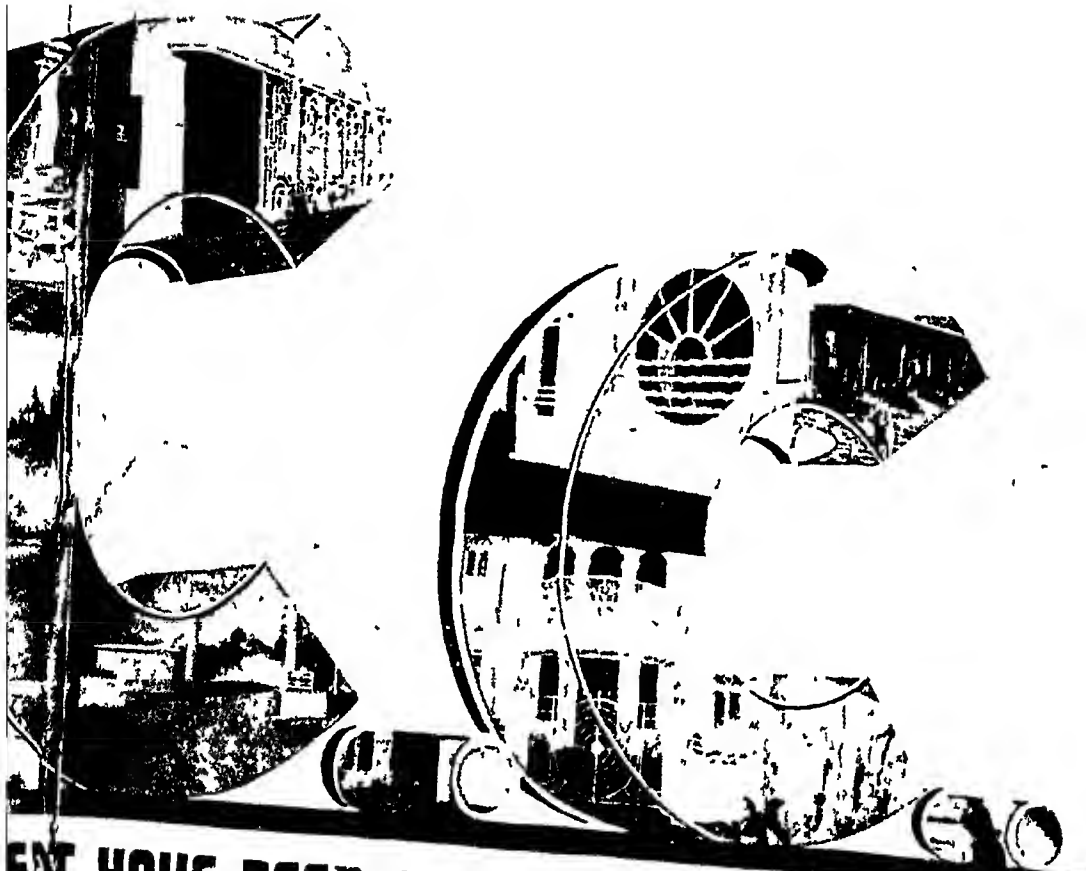


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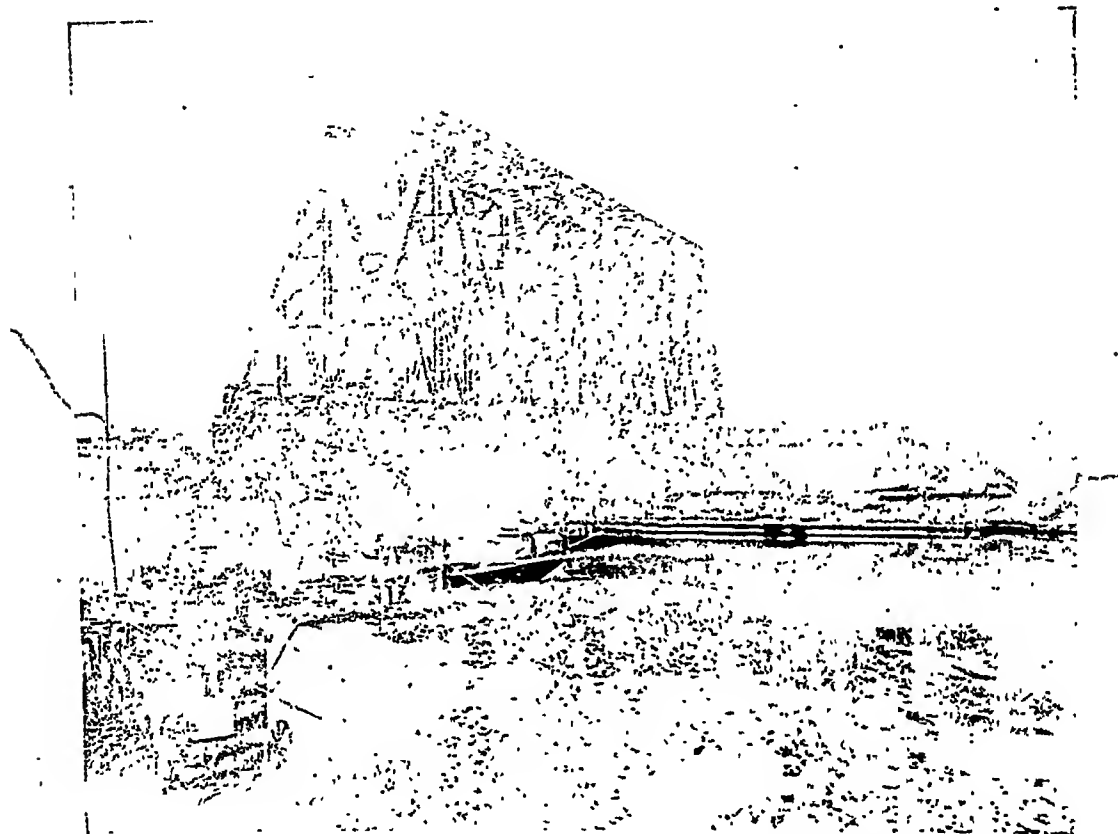
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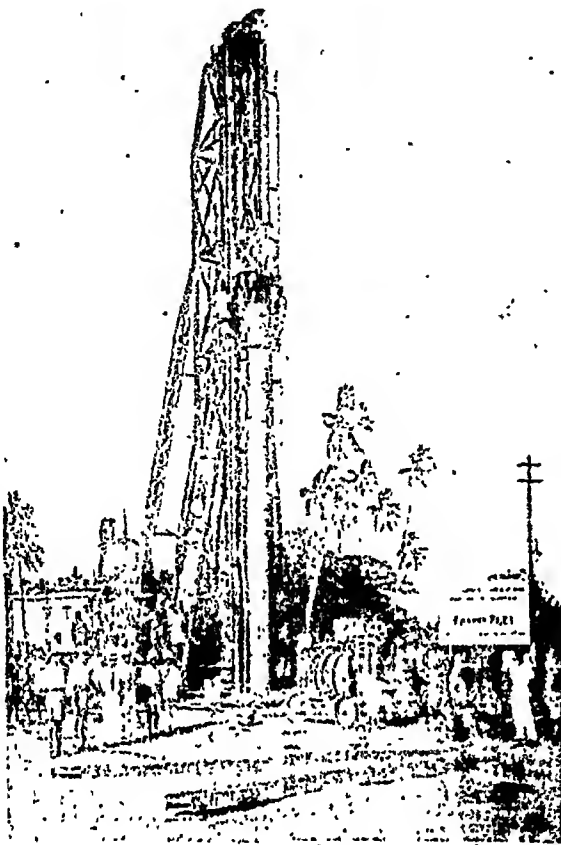
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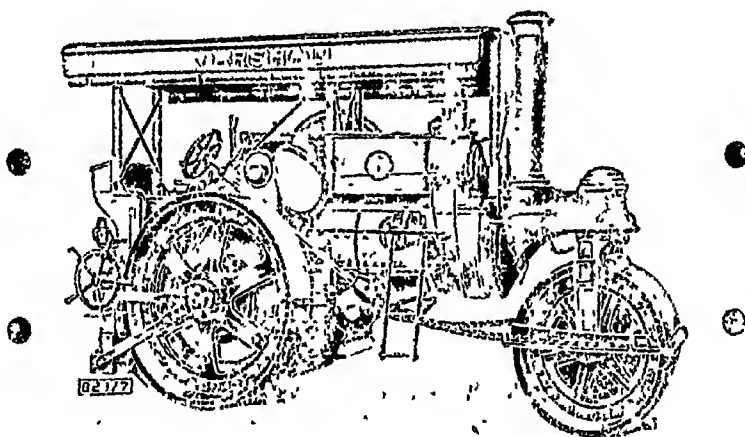
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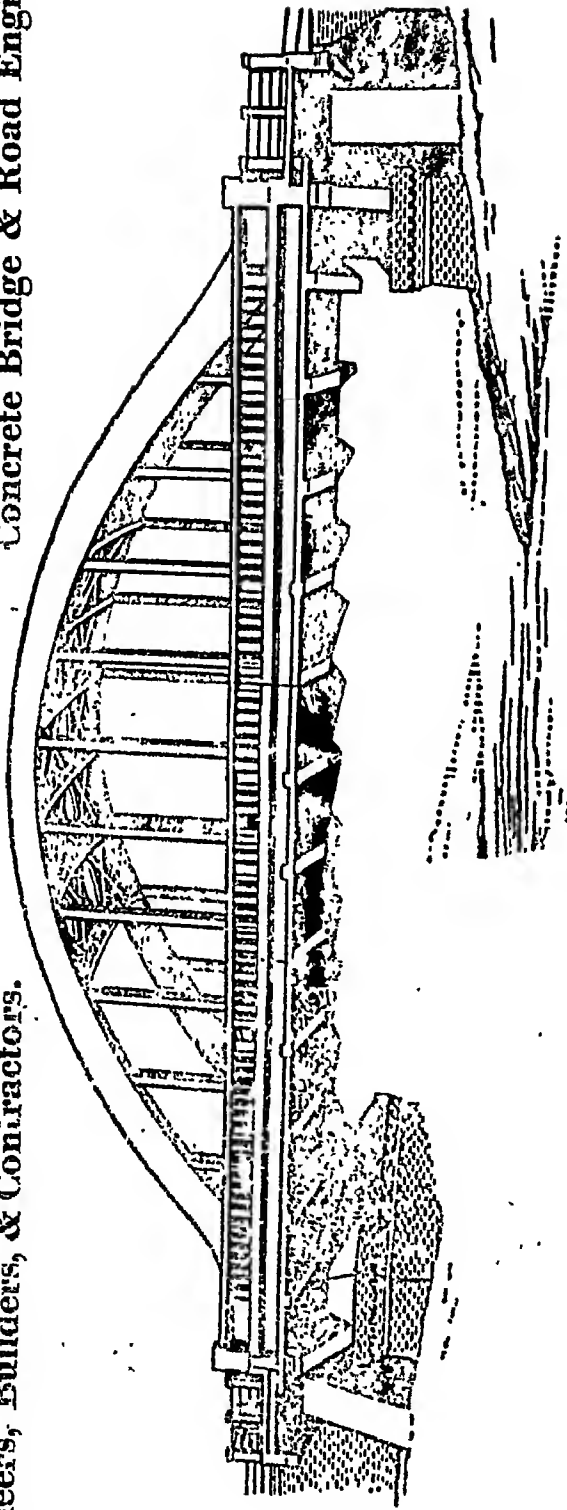
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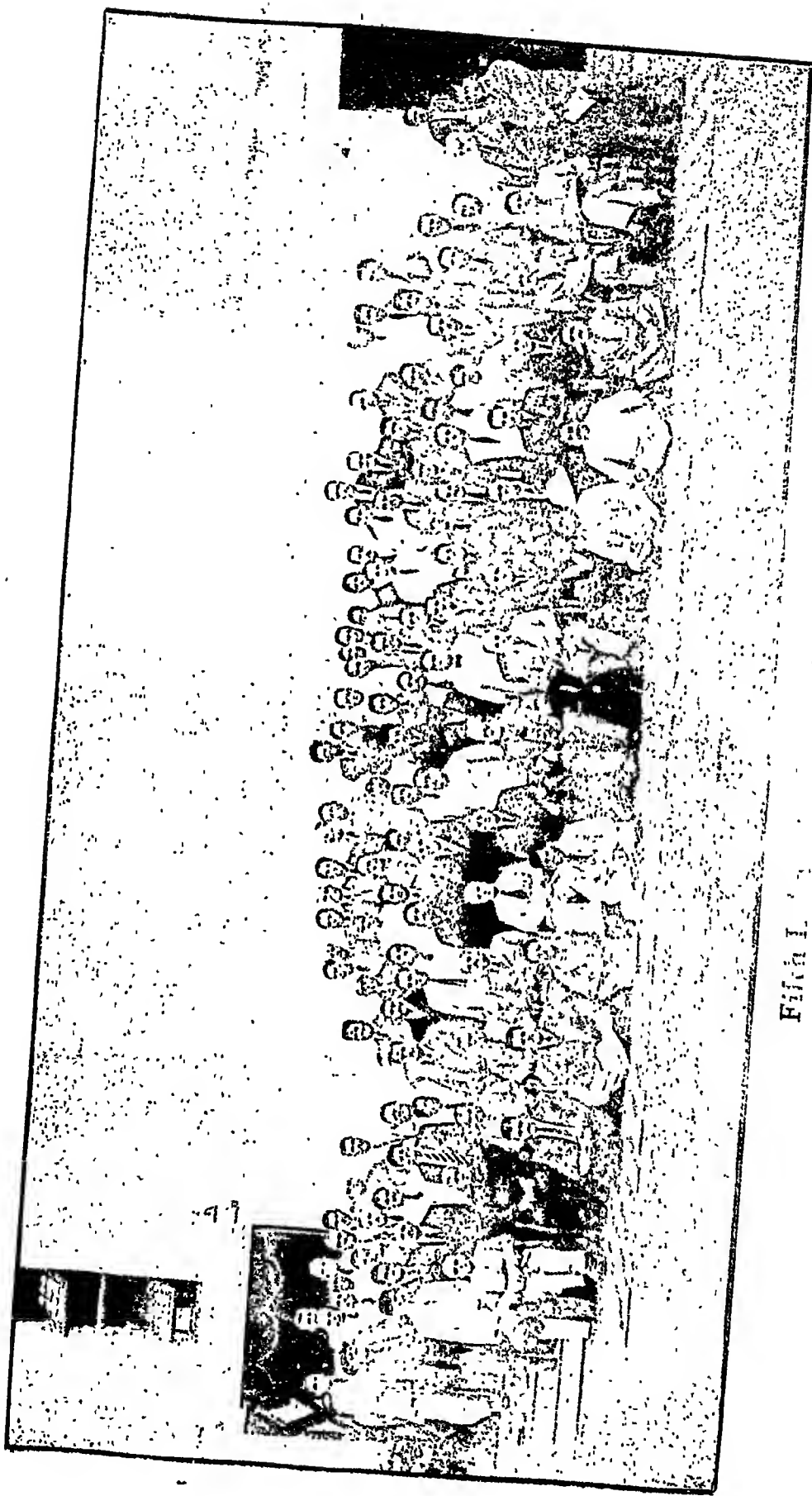


Fig. 1

Proceedings of the Fifth Meeting of the Indian Roads Congress.

Volume V.

Calcutta.

February 1939.

CONTENTS.

	PAGES
1. List of delegates	1—5
2. Presidential address by Mr. S. G. Stubbs, O. B. E., I. S. E., Chief Engineer and Secretary to the Government of the Punjab, Public Works Department, Buildings and Roads Branch, President, Indian Roads Congress. 1937 and 1938	5—10
3. Speech by the Honourable Maharaja Srischandra Nandy, M.A., M.L.A. of Cossimbazar, Minister for Communications and Works, Government of Bengal.	10—12

PAPERS.

4. Soils in relation to Roads, by G.W.D. Breardon. Paper No. N	1(n)—7(n)
5. Discussions on Paper No. N	7(n)—10(n)
6. Correspondence on Paper No. N	10(n)—12(n)
7. The Use of Soil Stabilization in Un-metalled and Me- talled Roads in India, by Sita Ram Mehra. Paper No. O (7 <i>photographs</i>)	1(o)—11(o)
8. Discussions on Paper No. O	12(o)—21(o)
9. Surface Treatment of Concrete Roads when outworn, by W. A. Radice. Paper No. Q	1(q)—8(q)
10. Discussions on Paper No. Q	9(q)—13(q)
11. Correspondence on Paper No. Q	13(q)—18(q)
12. Some Notes on Submersible Bridges, by D. Nilsson. Paper No. I (9 <i>diagrams</i> and 9 <i>photographs</i>)	1(i)—28(i)
13. Discussions on Paper No. I	29(i)—43(i)
14. Correspondence on Paper No. I	43(i)—45(i)
15. Design of Reinforced Concrete Bridges of Short Spans for Indian Roads, by Brij Mohan Lal. Paper No. J (8 <i>diagrams</i>)	1(j)—32(j)

	PAGES
16. Discussions on Paper No. J	33(j)—46(j)
17. Correspondence on Paper No. J (1 <i>diagram</i>) ..	46(j)—55(j)
18. Ribbon Development. by A. S. Trollip. Paper No. M (4 <i>photographs</i>)	1(m)—20(m)
19. Discussions on Paper No. M (2 <i>diagrams</i>) ...	21(m)—30(m)
20. Correspondence on Paper No. M	30 (m)
21. Layout of Roads, by R. Trevor-Jones, M.C. Paper No. K (II)	6(k)—17(k)
22. Discussions on Paper No. K (II) (1 <i>diagram</i>)	18(k ₂)—43(k ₂)
23. Collection of Material for, and Consolidation of, Water- bound Macadam, by R. Trevor-Jones, M.C. Paper No. K (I)	1(k) -5(k)
24. Discussions on Paper No. K (I)	6(k ₁)—25(k ₁)
25. Correspondence on Paper No. K (I)	25(k ₁)—40(k ₁)
26. Some aspects of Bituminous Road Construction in India, by Colonel G. E. Sopwith, M.C. and W. A. Griffiths. Paper No. L	1(l) -11(l)
27. Discussions on Paper No. L	12(l)—22(l)
28. Correspondence on Paper No. L	22(l)—24(l)
29. Revitalization of Tarred or Bitumened Surfaces by Mix- in-place methods using Cut-back asphalt, by Captain R. C. Graham, R.E. Paper No. P (1 <i>diagram</i> and 4 <i>photographs</i>)	1(p)—7(p)
30. Discussions on Paper No. P	8(p)—12(p)
31. A serious failure in the Painting of a Steel Highway Bridge, by W.L. Murrell. Paper No. R ...	1(r)—4(r)
32. Discussions on Paper No. R	5(r)—10(r)

APPENDICES

33. Appendix I.—Report of the Technical Sub-Committee to the Council of the Indian Roads Congress for the year 1936	13—17
34. Appendix II.—Report of the Technical Sub-Committee to the Council of the Indian Roads Congress for the year 1937	18—35
35. Appendix III.—Report of the Technical Sub-Committee to the Council of the Indian Roads Congress for the year 1938.	36—51
36. Appendix IV.—Discussions on the Resolution regarding Restriction of "Ribbon Development"	52—54

	PAGES
37. Appendix V.—Tours and other functions held during the Fifth Session of the Indian Roads Congress, Calcutta, February 1939	55—88
38. Appendix VI.—A Note on Experiments with Cut-backs of Bitumen, by Mr. P.C. Neogi	89—102
39. Appendix VII.—List of Papers in Annual Proceedings...	103—106
40. Appendix VIII.—List of Members (corrected upto 1st October 1939)	107 131
41. Index to Advertisers	(x)

Proceedings of the Fifth Meeting of the Indian Roads Congress held at Calcutta on February 14 to 18, 1939.

The Fifth Session of the Indian Roads Congress commenced at 3 p.m. on February 14, 1939, at the Hall of the Institution of Engineers (India), at No. 8, Gokhale Road, Calcutta. The following members of the Congress were present:—

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Mr. A. W. Nightingale, Superintending Engineer, Bellary.
Mr. T. Lokanathan, District Board Engineer Coimbatore.
Mr. K. S. Ramamurti, District Board Engineer, Anantapur.
Mr. B. Narashimha Shenoy, District Board Engineer, Calicut.
Mr. A. Lakshminarayana Rao, Tyagarajanagar.
Mr. P. K. Mukherjee, District Board Engineer, Masulipatam.
Mr. B. Satyanarayana, District Board Engineer, Rajamundry.
Mr. G. B. Sankaram, Assistant Engineer, Gudiwada.
Mr. B. Narayana Murty, L. F. Assistant Engineer, Vizianagram.
Mr. K. Srinivasan, L. F. Assistant Engineer, Narasapatam.
Mr. S. Ramanujacharya, Assistant Engineer, Anantapur.
Mr. N. T. Guanaprakasam, Assistant Engineer, Bezvada.
Mr. K. K. Nambiar, District Board Engineer, South Kanara, Mangalore.
Mr. T. Sekharan, District Board Engineer, Madura.

Bombay.

Mr. R. A. Fitzherbert, Superintending Engineer, Road Development, Bombay.
Mr. N. V. S. Murbi, Executive Engineer, Dharwar Division, Dharwar.
Mr. A. S. Adke, Engineer, District Local Board, Dharwar.
Mr. N. V. Modak, City Engineer, Bombay Municipality.

Bengal.

Mr. C. W. Tandy Green, Chief Engineer, Department of Communications & Works, Bengal.
Mr. J. Chambers, Superintending Engineer, Department of Communications & Works, Calcutta.
Mr. A. N. Bose, Superintending Engineer, Department of Communications & Works, Bengal.
Mr. J. A. Stein, Special-Officer, Road Fund Works, Bengal.
Mr. H. A. Keatinge, Executive Engineer, Rajshahi, Bengal.

- Mr. S. C. Chatterjee, Personal Assistant to the Chief Engineer, Department of Communications & Works, Bengal.
- Mr. T. K. Mitra, Executive Engineer, Department of Communications & Works, Bengal.
- Mr. J. C. Guha, Executive Engineer, Department of Communications & Works, Bengal.
- Mr. U. N. Mukherjee, Executive Engineer, Calcutta.
- Mr. S. C. Dam, Executive Engineer, Calcutta.
- Mr. J. N. Das Gupta, Retired Deputy Chief Engineer, Improvement Trust, Calcutta.

United Provinces.

- Mr. W. F. Walker, Executive Engineer, Meerut Division, Meerut.
- Mr. A. C. Mukerjee, Executive Engineer, Lucknow.
- Rai Sahib L. Fatch Chand, Secretary-Engineer, District Board, Bijnor.

Punjab

- Mr. S. G. Stubbs, O.B.E., Chief Engineer and Secretary to the Government of the Punjab, Public Works Department, Buildings and Roads Branch, Lahore.
- Mr. R. Trevor Jones, M.C., Superintending Engineer, III Circle, Public Works Department, Lahore.
- Mr. S. Bashiram, Superintending Engineer, II Circle, Rawalpindi.
- Mr. Brij Mohan Lal, Executive Engineer, Public Works Department, Lahore.
- Mr. Sita Ram Mehra, Communications Board, Public Works Department, Secretariat, Lahore.
- Dr. A. N. Puri, Physical Chemist, Irrigation Research Institute, Lahore.

Central Provinces.

- Mr. P. V. Chance, Chief Engineer, Public Works Department, Central Provinces and Berar, Nagpur.
- Rai Bahadur Sunder Lal, Superintending Engineer, Nagpur.
- Mr. D. P. Dave, Sub-Divisional Officer, District Council, Akola.

Bihar.

- Mr. W. L. Murrell, Superintending Engineer, Ranchi.
- Mr. S. A. Amir, Executive Engineer, Hazaribagh.
- Mr. S. K. Ghose, Assistant Engineer, Public Works Department, Darbhanga.
- Rai Bahadur U. S. Jayaswal, District Engineer, Muzaffarpur.

Assam

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North West Frontier Province.

- Mr. W. Lawley, Executive Engineer, Public Works Department, Mardan.

Orissa.

- Mr. A. Vipan, C.I.E., Chief Engineer and Secretary to the Government of Orissa, Public Works Department, Cuttack.
- Mr. M. N. Bhuyan, Assistant Secretary to the Government of Orissa, Cuttack.
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- Mr. M. Mahapatra, Cuttack.
- Mr. A. K. Sinha, District Engineer, Cuttack.

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- Mr. G. B. Vaswani, Assistant Engineer, Roads, Municipal Corporation, Karachi.

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- Mr. Jagdish Prasad, Assistant to the Consulting Engineer to the Government of India (Roads), New Delhi.

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- Mr. Chandrama Pershad, Assistant Engineer, Rewa.

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Western India States Agency.

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Mr. Dildar Hosain, Assistant Chief Engineer, Public Works Department, Hyderabad (Deccan).

Mysore State.

Mr. N. Lakshminarasimhaiya, Executive Engineer, Bangalore Division.

Mr. B. Krishna Rao, Executive Engineer, Mysore Division.

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Mr. Abdul Jabbar Khan, Executive Engineer, Rampur.

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- Mr. E. Hayward, C/o. Messrs. D. Wallie & Company, Konnagar, District Hoogly.

The Congress was formally opened by the Honourable Maharaja Sir Srischandra Nandy, M.A., M.L.A. of Cossimbazar, Minister for Communications and Works, Government of Bengal, who was accompanied by Mr. J. R. Blair, C.I.E., I.C.S., Secretary to the Government of Bengal, Department of Communications and Works.

In asking the Honourable Maharaja to open the Congress, Mr. S. G. Stubbs, O.B.E., President of the Indian Roads Congress, delivered the following address :—

On behalf of the Indian Roads Congress, I accord a most cordial welcome to you, Honourable Maharaja Srischandra Nandy and offer you our thanks for coming here today to open the Fifth Session of the Indian Roads Congress.

Before I request you, Sir, to declare the Congress open, I may say a few words reviewing its past activities. The first and preliminary meeting of the Indian Roads Congress was held at the instance of the Government of India at Delhi in December, 1934. This meeting was a great success and clearly established the necessity, which was being felt for a long time, of creating a society for the interchange of ideas and pooling of experience of road engineers, from all over India, in road construction and maintenance. The Society was formally constituted in 1936 and the Government of India were kind enough to undertake to finance the first three sessions of the Congress, and subsequently they financed the fourth Session also. But the Government of India have always held that, once the Congress had been established, the Governments of Provinces and States, and not the Central Government, would, in the nature of things, be in the best position to say whether its continued existence would be likely to be productive of material benefit in the provision of better roads at a reasonable cost and that, therefore, its continuance should be dependent upon the willingness of those Governments to pay the expenses of their delegates attending the annual meetings. We must all, I think, accept the reason behind this attitude and it should now be our business to continue to deserve the support of the Governments concerned. This arrangement has now been agreed to and this is the first session at which it is in force, and I think we might congratulate ourselves that the strength of this meeting is a sure sign that the authorities concerned are at present satisfied that we are doing valuable work. At the same time I must emphasise that the life and vitality of a body of this sort depend upon the willingness of individual members to contribute their quota of experience to the general pool and to come forward readily to contribute papers. It has been suggested that, owing to the time which it takes for the proceedings to be edited and printed and because the papers have to be submitted several months before the date of the Congress, in order that they may be considered and then be printed up and circulated, twelve months is too short an interval between meetings to provide for real continuity in the papers presented and the discussions thereon. But that, of course, is only one side of the question and the personal contacts and inspections for which these annual meetings afford opportunity are perhaps of equal value to if less spectacular than the presentation of papers and discussions thereon. Moreover in a country of the size of India, I feel that it might be difficult to sustain interest and stimulate the corporate spirit of the Congress, which is so necessary, if meetings were held at substantially longer intervals. This is a matter which the Congress, will have to set itself to decide if not this year possibly next year, and in arriving at a decision I have no doubt that members will apply their minds to the problem from the point of view of the essential objects of the Congress. Be that as it may, we are this year standing more or less on our own feet. We have by a careful hushanding of our resources built up a bank balance of about Rs. 15,000/- and we are proposing to separate the office and to become more or less independent of the Government of India save for an annual subsidy of about Rs. 4,000/- which is necessary to bridge the gap between our estimated income and expenditure and which we trust the Government of India will be able to contribute.

The second, third and fourth sessions of the Roads Congress were held at Bangalore, Lucknow and Hyderabad (Deccan) respectively. The papers read and discussed at these meetings covered a wide range of subjects dealing with modern methods of layout, construction and maintenance of roads, bridge foundations and superstructure, road research, traffic statistics, safe wheel loads etc. Over 50 papers have been presented and discussed during the last four Congresses and we have eleven papers dealing with soil research in application

to roads, design of submersible and high level bridges, ribbon development, principles of road design and construction, etc. to discuss at this session. It will be conceded, I hope, that all this represents solid and serious work on the part of the Congress.

The Roads Congress has standardised units of weight, measure and cost to be used in road specifications, estimates and reports : has prescribed standard method and form for recording particulars of experiments carried out on roads ; has standardised specifications for sizes of stone metal and nomenclature for bituminous materials and types of construction. It has also laid down standard method of recording traffic statistics and has given attention to the standardisation of Road Signs.

The Roads Congress has been responsible for the Government of India undertaking to finance the establishment of a Test Track at the Government Test House, Alipore, and a scheme of soil research in connection with earth roads. Actual tests on roads constructed under varying conditions of climate and traffic using different materials in different proportions would take years of experimentation while comparative results could be arrived at in a short time on the Test Track. These results should be of invaluable assistance to road engineers throughout India and should save much time and money that is now being spent on scattered experiments all over the country.

The problem of earth roads is as colossal as it is difficult, but its importance to a vast population in the countryside, whose prosperity depends on transport facilities for agricultural produce, demands of the road engineer a great deal of thought and attention. The study of soils in their relation to earth roads and road foundations has been made extensively in America and other foreign countries, but so far in no country in the world has an earth road been developed which would stand the iron-tired bullock cart typical of this country. It is realised that any earth road is bound to cut up to a greater or less extent by the thin hard tyre of the common bullock cart and our present aim is to produce, with reasonable expenditure, a surface which would remain compact and retain moisture for a considerable length of time and which could at intervals be regraded or levelled with a drag when conditions of rainfall are favourable. Soil research is now being carried out by the soil physicist appointed by the Government of India at the Punjab Research Laboratory, Lahore and a road engineer has been appointed by the Punjab Government to act as a liaison officer between the laboratory and the field. A number of soils in the Punjab and Sind have already been examined and very valuable information has been collected as a result of which field experiments on stabilisation of earth roads, subgrades and berms are being carried out in the provinces referred to above under the guidance of a sub-committee of this Congress. The results of these experiments will be made available to the Congress at this and subsequent sessions.

Yet another important achievement to which the Congress can lay claim is the publication of Standard Specification and Code of Practice for Road Bridges in India, which is, I believe, now on the shelf of every progressive road engineer in this country. This publication should result in the simplification and standardisation of designs and consequent economy in the manufacture of structural members and expedition in the construction of bridges. The next step which we have to take will naturally be towards the preparation of typical designs of various kinds of bridges and culverts for the standard loading. This

is a big undertaking but, none the less, very desirable. With the co-operation of experienced engineers in the services and in business it should not be difficult to achieve this object.

The Roads Congress has also made a beginning towards the preparation of a Code of Practice for roads. Papers dealing with the construction of water bound and bituminous surfaces and layout of roads have been brought forward for discussion at this session. After discussion the technical sub-committee of the Congress will prepare a draft for incorporation in the proposed Code of Practice. More subjects will be dealt with in a similar way and it is hoped the booklet will be in a fairly complete form before long.

The scope of activity for a body like the Roads Congress is very wide indeed but, as in the case of other similar organisations, its proper functioning will depend on its financial position. The Congress is yet in its infancy and has not got a decent reserve. On the other hand it is hardly able to balance its budget inspite of the promised financial assistance of the Government of India. The publication and distribution of technical books and literature and the preparation of standard designs involve financial risk which the Congress cannot at the present stage safely bear. It, therefore, looks up to the Government of India, Provincial Governments and Indian States for greater measure of financial assistance towards its technical activities. It would be a pity if the usefulness of the Congress is impaired on account of lack of funds. That the Congress is popular is evident from the rapid increase in its membership which now stands at 400. There are, I believe, many road engineers who have not yet realised the benefits of membership and I would appeal to Chief Engineers of Provinces and States to impress upon the engineers under their control the desirability of joining this Congress in order to keep in touch with the latest developments in road engineering and research, and improve their knowledge and efficiency.

One of the objects of the Congress is to provide a medium for the expression of the corporate opinion of Road Engineers in India on problems affecting the good of roads, and while we must be careful to confine ourselves to matters which are strictly our business and not to wander too near the border line between administration and politics, it is, I think, our concern and our duty to offer our opinion upon matters of administration which concern the provision of good roads. The advent of motor transport has revolutionised the problems of road construction and maintenance and there appears to me to be something of a lag in adjusting our organisation and finance to the new conditions. *Prima-facie* it is improbable that old and time-honoured arrangements which were suitable 20 years ago must necessarily be good at the present day and in the future with which we are faced. I have nothing but admiration for the way in which the general body of the engineers of local bodies discharge their functions, but, at the same time, it is a matter for serious consideration whether a greater measure of centralisation of road administration within the provinces is not now necessary. Problems and difficulties repeat themselves in neighbouring districts and while through this Congress we provide for the interchange of ideas and experience, it is questionable whether the official organisation which leaves the several engineers of District Boards to do good "You in your small corner, and I in mine," without adequate knowledge of what each other are doing,—possibly repeating the same mistakes and the same costly experiments—is not now an anachronism. Similarly in the case of provision for maintenance one hears on many sides the complaint that, while motor transport is rapidly

developing and incidentally bringing in revenue through provincial motor taxes, the provision for maintenance has not been increased proportionately while the provision of funds for reconstruction in surfaces which can be maintained under modern conditions more economically than the old water-bound macadam is inadequate to make any substantial impression upon the problem. Here again I think that it would be legitimate for this Congress to draw attention to these two matters, and in particular to suggest that there are parts of India where a careful and detailed review of the provision which is necessary for the maintenance of existing road surfaces under present day traffic conditions, is already overdue. I believe that in India we have reduced the question of economical road maintenance to a fairly fine art and that the figures which would result from such a review, if compared with the provision of 15 or 20 years ago, when roads carried only a fraction of the traffic they now do, and the problem of superimposed destruction by two different types had not arisen, would show that we are, as Engineers, able to meet the new conditions with a very modest increase of funds. But if adequate provision is delayed, much greater expenditure on reconstruction will be necessary.

Before closing I would like to give you an outline of the organisation and cost of maintenance which exists at the present day in my own province, not because I wish to claim any superiority but merely because after many years' association with road matters in that province I feel myself qualified to explain our organisation and finance and what we think we have been able to effect as a result. For many years past the Punjab Government have always recognised the important principle that the scope of any road programme is limited more by the funds required to maintain in satisfactory condition existing as well as new roads (especially metalled roads) rather than the funds required for new construction. With this principle in view not only have adequate funds been provided for maintenance but the cost of maintenance has been considerably reduced by modernising surfaces on a very large scale. Ten years ago out of a total mileage of 1780 miles only 50 miles were surface painted and the cost of maintenance was approximately Rs. 1,700/- per mile per annum. At the present time 3250 miles have been surface painted out of a total mileage of 3400 and the cost of maintenance has been reduced to less than Rs. 1,100/- per mile per annum. It is expected that the latter figure will be reduced still further during the next 4 or 5 years.

The Punjab Government have not only confined their activities to provincial roads but their ultimate object is also to bring District Board roads (both metalled and unmetalled) up to the standard of Provincial roads. With this object in view some 350 miles of District Board roads have been provincialised during the last 2 years and about 450 will be provincialised this and the next year. This will not only considerably increase the surface painted mileage in the Province but will enable District Boards to improve the remaining roads in their charge. Apart from this the Punjab Government have appointed two special road officers, namely, a Superintending Engineer (Roads) who is also Secretary, Communications Board and as already mentioned an Assistant Engineer, whose main function is to carry out experiments on soils in connection with earth roads. The functions of the former include activities both on provincial roads as well as District Board roads. This officer is assisted in the control of the activities on District Board roads by all the Executive Engineers in the Province who have recently been appointed ex-officio members of District Boards. In this way all road activities have been centralized and are controlled by the Chief Engineer of the Province.

Sir, I have taken much of your time in briefly reviewing the activities of the Indian Roads Congress and expressing my views on certain problems. It is now my pleasant duty to request you to declare this fifth meeting of the Congress open.

The Honourable Maharaja then addressed the Congress as follows:—

MR. PRESIDENT AND GENTLEMEN,—

It gives me great pleasure to welcome you to Calcutta on behalf of the Provincial Government and I should like to thank you for the reception which you have given me. I trust that you will enjoy your stay here; and when I say so I am thinking not only of the pleasure which you will no doubt derive from your discussions but also of the pleasure to be derived from the various amenities which this City can offer. This is the first time that you as a Congress have visited Calcutta and I have no doubt that you will find that it differs in many ways from any of the places in which you hitherto assembled. As a large port and centre of industrial and commercial activities it is vitally interested in the improvement of all forms of transport, and appreciates the thesis of those economists who consider that transport is an essential element of production. Calcutta is the most urban of the places at which your Congress has assembled, and I am sure that you must have been impressed by certain outward signs of prosperity and wealth, including the existence of some fairly good roads within the City and in its immediate neighbourhood.

On the other hand the Province of which this town is the capital is probably, with the exception of the industrial area near the City, less highly developed in regard to road communications than the Provinces or States whose capitals you have hitherto visited. We cannot even say that a series of magnificent roads radiate from Calcutta; and some people may say that among the amenities which I suggested the town might offer, facilities for pleasure trips by roads cannot be included. The principal reason for the backwardness of this Province in the matter of road development is fairly obvious,—it is a deltaic area exposed to the vagaries of the monsoon and of a net-work of rivers especially in the eastern areas where huge tracts remain under water for many months of the year. These conditions I fear have made people despair of ever seeing a system of broad highways in this Province, and led them in the past to rely largely on communication by rail and river. It is also just possible that in our eagerness for too much railway development in the past we neglected the legitimate demands of road-making as an important means of communication. Then again there is the view, held by a good many people until recently, that road-making was merely an extravagant fad on the part of a few officials—a fad which diverted money which might be spent to greater advantage in other directions. The development of motor transport has, however, brought about a change; and the desire of large numbers of people to enjoy the advantages which that form of transport so obviously offers has led to the development of an interest in roads which sometimes proves embarrassing to a Minister of Communications who is called upon to say in the Legislature what Government propose to do with regard to the construction of a road between two places of which he may never have heard, in some distant part of the Province.

It is perhaps a sad legacy of the past that at the beginning of the present era of mechanical transport, we in this province were not road-minded, and our organisation for the study and execution of projects of road development was very small. We have, therefore probably been much slower than other

provinces in making a beginning, with the result that we have had many unkind things said about us by critics both within the province and outside. I think, however, that we are now getting into our stride and once we have made up our mind as to the general line of development to be followed, extensive construction will be carried out. I think I can tell you at this stage that we are at present concerned with a comprehensively planned scheme for road development in Bengal prepared by our Special Officer after laborious work for years together. In the course thereof we shall have an ever-increasing need of that knowledge of new methods which is likely to be made available in this country as a result of your annual deliberations and the research which you carry out between one Congress and another. There has been a serious aggravation of public health problems in this part of India and we in Bengal naturally feel much concerned over the matter which has intimate connections with Road and Railway Development. We shall certainly watch with keen interest if your deliberations can bring forward some further material contributions in this regard.

You have referred, Mr. President, to the establishment of a test track at the Government Test House at Alipore, and to the scheme of soil research in connection with earth roads. Your Congress is to be congratulated on getting the Government of India to finance these undertakings, and the provinces have reason to be grateful if it was on the recommendation of the Congress that the Central Government have agreed to meet the expenditure. We in Bengal are naturally very glad to have the test track here in Calcutta and it was a very interesting experience for me recently when I visited the Soil Experiment Laboratory.

I think, Mr. President, that you have done well to emphasize the importance to this country of the problem of unmetalled roads. I say this because there is a danger of the impression getting abroad that now-a-days road engineers are concerned only with making roads that are fit for motor transport, overlooking earth roads which are of such great importance in the transport of agricultural produce. The unmetalled road and the bullock cart, hard though the latter is on the former, are likely, for many years to come, to be the principal factors in goods transport for the millions of people who are engaged in the cultivation of the soil. It will be a great achievement if as a result of the work done at the Soil Experiment Laboratory means can be found so to improve unmetalled roads that they will be able to carry bullock cart traffic without deteriorating as rapidly as they do now. But it is not only the *kutchra* road which suffers from the bullock cart; the metalled road too is exposed to serious risk. I have no doubt that you have heard suggestions that bullock cart traffic should be discouraged on new roads. I doubt however whether public opinion would favour any degree of restriction that would do much good and immediate restriction on a large scale would probably very seriously affect the general transportation of goods. For the present therefore we must see whether anything can be done to improve the bullock cart and to increase the power of resistance of the metalled road, so that the man who uses a bullock cart will enjoy the benefit of a good road surface, while the man who uses a motor vehicle will not have cause to anathematise the user of the more primitive form of transport. At this point I should like to say that when I talk of the man who uses a motor vehicle I am not thinking only of the owner of a luxurious motor car or the shareholder in a big mechanical transport business, I am thinking also of the motor bus passenger and I remember the saying that the bus is the poor man's car.

Improvement in construction should lead to a reduction in the average cost of maintenance which is an element in road expenditure that many enthusiasts for new construction are apt to overlook. It is important that wider recognition should be given to the principle mentioned by you that the scope of any road programme is limited very largely by the funds required to maintain old and new roads in a satisfactory condition. I am glad to say that in this province in recent years there has been a considerable reduction in the average cost of maintaining a mile of road. Tax-payers are looking forward to a further reduction as a result of the researches of road engineers like yourselves. We in this province are particularly anxious to see a further reduction because the cost of original construction is very high. We have to go far afield for our metal with consequent heavy expenditure on transport by rail, road and river; and as I have said already, we have to take our roads over large rivers and other water ways which necessitate to an extent that is possibly not realised in other parts of India, the construction of expensive bridges and culverts. That is a reason why we should be grateful to this Congress which has to its credit the publication of standard specification and Code of Practice for Road Bridges in India; we should be grateful because this publication is likely to lead to economy and expedition in construction. We shall take the keenest interest in what you have said will be your next step in this department of road engineering, viz. the preparation of typical designs of various kinds of bridges and culverts for standard loads.

Mr. President, I was very glad to hear you say that while you and your colleagues of this Congress are primarily concerned with technical problems of construction and maintenance, you deem it your duty to offer an opinion on matters of administration connected with road communications; your remarks on this subject towards the end of your address were of very great interest to me. You said that in your province all road activities have been centralised and are controlled by the Chief Engineer. Whether our policy will develop on similar lines or not I cannot say at present, but the experience of the Punjab will be extremely useful to us. Certainly, since the creation of the Road Development Fund very much more work on the planning and construction of roads has been done from provincial head-quarters than was previously the case; and I think that local authorities will, to an ever-increasing extent, appreciate the value of co-operation with each other, and will look towards head-quarters to guide and co-ordinate their activities while retaining complete independence in regard to communications of local importance.

I was very pleased to learn that your Congress is now placed on a fairly sound financial basis. I cannot of course say how far the Government of this Province will in future contribute to your resources, but I trust that if you go on as you have begun, it will not be difficult to persuade the Finance Minister that a request for a contribution from provincial revenues should receive his very favourable consideration. You will be able to point to the benefit which officers of the Communications Department derive from their contact with other engineers through the medium of the Congress. Another argument in your favour will be your achievements in reducing the cost of construction and maintenance as a result of your researches.

In conclusion, Gentlemen, I offer you my thanks for inviting me to open your Conference and I trust that you will take away with you very pleasant memories of your Calcutta Session.

THURSDAY, FEBRUARY 16, 1939.

PAPERS N AND O.

Mr. S. G. Stubbs (Chairman):—As Mr. Breadon is not here today and Mr. Sita Ram Mehra has consented to introduce his paper for him, I think it would be more convenient for Mr. Mehra to introduce the two papers together. I would call upon Mr. Mehra to introduce both the papers.

The following two papers were then taken as read:—

PAPER No. N.

SOILS IN RELATION TO ROADS.

A BIBLIOLOGICAL STUDY.

By

G. W. D. BREADON,
District Engineer, Gurdaspur.

Few branches of engineering are passing through such varied and rapid changes as road engineering, due primarily to the motor-vehicle having become the predominating factor in road transportation.

In this Paper the objective is to deal exclusively with soils in their relation to roads—a subject that is of paramount importance to the engineer employed on road making.

Whatever the top surface of a road might be it should be able to resist the wearing action of the traffic passing over it. For light traffic in India earth-roads are the most economical, but where traffic is heavy a hard surface has to be created. Such hard surfaces help to protect the subgrade against the softening effects of water and by distributing the load of moving vehicles over a large area of the underlying soil the subgrade disturbance is materially reduced. It, therefore, offers firmer support to the superimposed crust.

Road improvement does not necessarily mean metalling or paving the surface. Earth roads are improved by grading and draining, also by surface treatment with calcium chloride or oils and by mixing clay with sand or sand with clay, also by coating with gravel, kunkur or other hard binders obtainable locally.

According to the system of mechanical analysis adopted by the Bureau of Chemistry and Soils in America, soils are divided into *grain sizes* or, as is termed in America, "Separates", these are as under:—

Name of soil.			Size of particles.		
Clay	below 0.005	millimetre.
Silt	0.005 to 0.05	"
Very fine Sand	0.05 to 0.1	"
Fine Sand	0.1 to 0.25	"
Sand	0.25 to 0.5	"
Coarse Sand	0.5 to 1.0	"
Fine Gravel	1.0 to 2.0	"

The physical properties of a soil effect its behaviour on the road and it is important to know all about these properties. The physical characteristics of soils are Contraction and Expansion, Plasticity, Elasticity, Absorption and Permeability.

The road engineer should be able to say which characteristics are due to the component parts of the soil itself, which result from its structure and which are caused by environments. His knowledge of soils should be such that he can at once lay his finger on soil defects which produce weaknesses

and faults in the metalled road or pavement and he should be familiar with the physical characteristics of soils and their behaviour when subjected to actual traffic conditions.

Soil characteristics that are usually investigated are (1) *The liquid limit*; (2) *The plastic limit*; (3) *The plasticity index*; (4) *The shrinkage limit*; (5) *The centrifugal moisture equivalent*; (6) *The field moisture equivalent*; (7) *The lineal shrinkage* and (8) *The volumetric shrinkage*.

In connection with all these characteristics it is necessary to determine the *moisture content*, i.e., the percentage of moisture in the soil expressed in terms of the dry weight of the soil particles, for example if a sample weighs 30 grams when wet and 24 grams when dry, the moisture content would be

$$\frac{30-24}{24} \times 100$$

$$= \frac{6}{24} \times 100 = 25 \text{ per cent.}$$

Liquid Limit.—Soil mixed with water so that it can flow is in a *liquid state* and the minimum moisture required to bring it to that stage is the **LIQUID LIMIT**.

Laboratory tests have determined the following comparative figures for liquid limits for soils :—

Sands 20, Silts 27, Clays 100, Diatoms 163, Colloids 399, Mica Flakes 123, and Peats 445.

Thus a liquid limit between 20 and 40 might indicate a mixture with sand or silt predominating, while limits higher than 40 point to the presence of mica, diatoms, organic matter, clay or colloids.

Mica is the name given to a group of Silicates having a perfect basal cleavage into thin, tough and shining plates, formerly used instead of glass. Mica-Schist and Mica-Slate are both laminated rocks.

Diatoms.—A diatom is any individual of the genus *Diatoma* or of the order *Diatomaceae*, a group of microscopic algae with siliceous coverings, which exist in immense numbers at the bottom of the sea, multiplying by division or conjugation, and occurring as fossils in such abundance as to form strata of vast area and considerable thickness.

Colloid.—Chemically an uncrystallizable, semi-solid substance, capable of only very slow diffusion or penetration. Colloidal matter is the gelatinous or gluey substance found in clays of a sticky nature. In soil classification anything in clay measuring 0.001 millimetre in diameter is termed *Colloid*.

Peats embrace all kinds of decayed and partly carbonized vegetable matter found in boggy places and used as fuel.

Plastic Limit.—The minimum amount of moisture needed to knead a soil so that it can be rolled out into strands of $\frac{1}{8}$ th inch diameter is termed the *Plastic Limit*. Silts, clays and colloidal clays are plastic, while sand, peats, mica and diatoms crumble away when rolled and consequently have no plastic limit. It has been determined that silt has an average plastic limit of 20, clay an average of 45 and colloids an average of 46.

Plasticity Index.—This is taken as the difference between the liquid limit and the plastic limit. This index shows the cohesiveness of a soil and indicates its power to change its shape without appreciably altering its

volume. The plasticity index of sand is fixed at zero, because it has no plastic limit. The same applies to peat, mica, and diatoms. The classification of soils by Atterberg with regard to plasticity indexes is as under :—

Friable	...	... less than 1
Feebly plastic	...	... 1 to 7
Medium plastic	...	... 7 to 15
Highly plastic	...	... greater than 15.

Shrinkage Limit.—Evaporation of water causes shrinkage in a soil up to a certain degree, beyond which decrease in volume does not occur. At this stage the soil has reached its shrinkage limit, in other words the moisture content at the stage when the soil changes from the semi-fluid to the solid state is the shrinkage limit. Between the plastic and the shrinkage limits no direct connection has been established, but it is generally known that the smaller the shrinkage limit, the greater the volume change corresponding to a given variation in the moisture content.

Referring back to the plasticity index classification the shrinkage limit may be given as follows :—

Friable soils	...	... between liquid limit and 50 per cent of that limit.
Feebly plastic	...	... 25 to 30 per cent.
Medium plastic	...	... 20 to 25 per cent.
Highly plastic	...	... 15 to 20 per cent.

Moisture Equivalent.—It is necessary to distinguish between *impermeable*, *permeable* and *porous soils*. This is effected by subjecting the soils under centrifugal force to a pressure of 28.5 pounds per square inch. The moisture content of a soil, which has reached saturation point and then, for an hour, subjected to centrifugal force equal to one thousand times the force of gravity, is called its *centrifugal moisture equivalent*. In this manner we can readily distinguish the impermeable soils—clays and colloidal clays—from permeable soils—soils with sand, silt, flaked-clay, mica, peat, diatoms etc., predominating, and from sand, which is porous. This test shows also *the capillarity of the soils*. Thus sand, which is porous and allows the free passage of water through the soil, has but little capillary attraction and merely bulks slightly when wet. On the other hand capillary action in permeable soils result in frost-lift and expansion-fractures.

Field Moisture Equivalent.—Mr. A. G. Bruce defines field moisture equivalent as the maximum percentage of water a soil will absorb when its moisture content is gradually increased by adding water. For sands the field moisture equivalent indicates *porosity*, whereas, in the case of moist compressed soils, it indicates the degree to which they can absorb water and expand and the degree of *cohesion* they possess.

A soil is apt to contain expansive materials, such as mica, in detrimental quantities, when the field moisture equivalent is either equal to or greater than its centrifugal moisture equivalent. Thus harmful micaceous silts can easily be detected.

Lineal and Volumetric Shrinkage.—Roll out, as uniformly as possible to a length of about 18 inches and a diameter of about 2 inches, a quantity of soil that has been wetted with water equal to field moisture equivalent and measure it in the wet; next let it dry and then measure again and work out the per cent shrinkage. In order to determine the volumetric

4 (n)

shrinkage the following curve diagram shall have to be used. Below it is another diagram for determining the shrinkage limit with the field moisture equivalent as the basis for determining the shrinkage. For reliable comparison of volume changes the amount of water to be applied to soils should be based on the total surface area of soil particles, hence the field moisture equivalent has been used as a basis in the diagram.

Diagram No. 1.

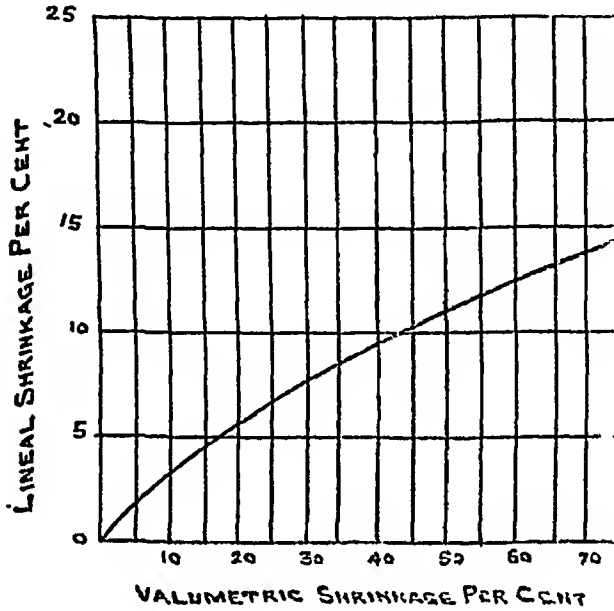
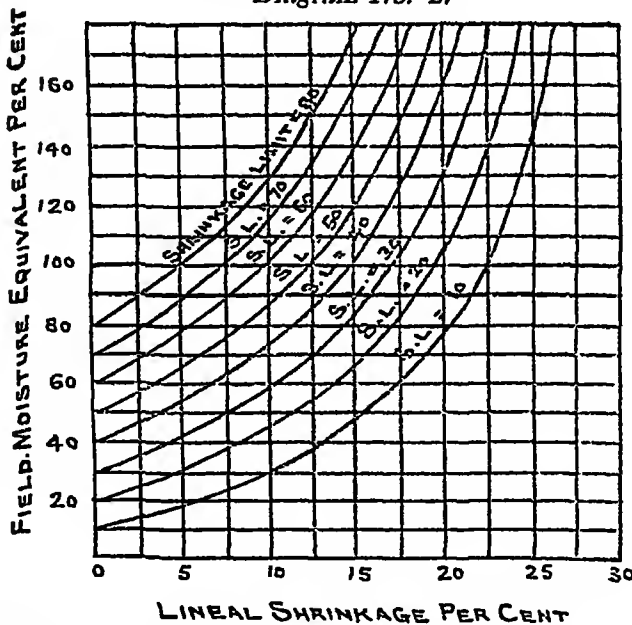


Diagram No. 2.



It is generally accepted that a lineal shrinkage of 5 per cent for which the corresponding shrinkage in volume is 17 should be regarded as the maximum permissible value for a good soil. (See Diagram No. 1).

When the liquid limit of a colloidal soil exceeds 35 (See Diagram No. 2) the shrinkage in volume is likely to exceed 17 per cent and hence the lineal

shrinkage is likely to exceed 5 per cent. In arid regions in the hot season the subgrade will dry out and shrink leaving the hard road surface without support. Clays change more in volume than silts, while sands remain more or less constant depending on their degree of porosity. From this it is clear that volume change depends on soil particles—the finer the particles the greater will be the change in volume, while coarse sands will show no appreciable change.

It might here be pointed out that the field moisture equivalent, the lineal shrinkage and the shrinkage limit are inter-related and with the help of the curves in the diagram the shrinkage limit can be determined from the other two values. First of all locate the intersection of the lineal shrinkage (vertical line) and the field moisture equivalent (Horizontal line). Then estimate the value of the shrinkage limit by finding the position of the point with respect to the curves. The attention of road-engineers is particularly drawn to this paragraph for, in addition to surface waves produced by a roller, the drying out of the subgrade has a great deal to do with "corrugation", as also "heaving".

The stability of a soil depends on the character of the soil and the resistance that it offers to loads passing over it is contingent on INTERNAL FRICTION of its component particles, COHESION between particles, CAPILLARY PRESSURE, ELASTICITY, and LIABILITY TO CHANGE OF STATE UNDER EXTERNAL CONDITIONS.

Clays are highly cohesive; sands are high in frictional resistance; micæ, diatoms and organic matter are elastic and rebound when pressure on them is removed and since they cannot be permanently compacted they make bad subgrades. Sand has no cohesion, but great frictional resistance and its bearing capacity increases under heavy load. Clay has cohesion, but hardly any frictional resistance, especially when soft and its bearing capacity is very low. The finer the soil particles the more variable are the cohesive and frictional properties of the soil under field conditions. The resistance due to cohesion does not depend on external pressure, whereas external pressure increases frictional resistance. Molecular attraction of water, or capillary pressure, causes surface friction between soil particles and produces a certain amount of cohesion. Cohesion and internal friction depend not only on the composition of the soil but on the state of the soil—whether it be wet or dry.

Contraction and expansion in the volume of a soil are caused by the throwing off of water in the first case and the absorption of water in the next. The capillary pressure in a soil in liquid form is Zero and no further change in volume can take place by the addition of water, although the particles will disintegrate and the soil flow. The semi-solid stage is reached when evaporation occurs and capillary pressure is developed. This pressure goes on increasing as evaporation progresses and shrinkage occurs until the shrinkage limit is reached, when capillary pressure and internal resistance to further reduction in volume are balanced. After this further evaporation merely causes capillary tubes to merge into the soil without causing shrinkage. Clays, colloids and micæ, which possess both cohesion and capillarity in large amounts, are highly expansive soils.

In the case of sand, a certain amount of bulking does take place when a moderate quantity of water is added to it. This spreads in the form of a thin film over the sand particles and pushes them slightly apart, but this

volume again reduces when the point of saturation is reached and the voids are filled. Thus wet sand reverts to the original volume of dry sand.

The interstices, such as pores or voids, in a soil determine its porosity and soil density is measured by its porosity, which in itself depends on the shape and disposition and proportion of the soil particles. The loosest soil consists of round particles of uniform size. A more compact soil contains particles both large and small. Angular particles, like chips do not compact so well as round particles of varying sizes. Cubes pack better than flats. Whether soil particles are large or small porosity does not alter as long as particles are of uniform size.

Porosity can be graded as under :—

Small	...	...	When less than 5 per cent.
Medium	...	...	Between 5 and 20 per cent.
Large	...	...	Greater than 20 per cent.
High	...	...	Greater than 50 per cent.

Most soils fall under the last named class.

Porosity may be found by the formula

$$P = \frac{V_v}{V_s + V_v} \times 100$$

in which P = Porosity

V_v = Total volume of voids in mass of soil.

V_s = Absolute volume of soil particles in mass.

There is also another formula

$$P = \frac{e}{1 + e} \times 100$$

in which e = Void ratio; given in the following table for the sake of simplification :—

Soil.				Void ratio at Liquid Limit.
Sand	...	...	...	0.54
Silt	...	...	...	0.71
Organic matter	...	...	...	2.00
Clay	...	...	...	2.65
Diatoms...	...	...	...	3.19
Mica	...	...	...	3.44
Colloids	...	...	...	8.18

When a soil changes volume on account of moisture content, the rate is proportional to the difference in the volume of moisture in it, and the constant that expresses the change ratio in soil volume to moisture content is called *Shrinkage Ratio*.

Bulking of Sand.—When a moderate amount of water is added to sand it bulks, but this bulking is not the same as the expansion due to capillary pressure.

Permeability.—The rate at which water passes through a soil to a sub-drain can be determined by the formula :—

$$V = K \frac{h}{2b}$$

in which V = Velocity in centimetres per second.

K = Coefficient of permeability.

H = Difference in elevation between sub-drain and highest ground-water level under hard crust, in centimetres.

b = Horizontal distance from drain to point at which h is measured in centimetres.

The value of K depends on soil type, thus

Coarse Sand	...	...	0.02
Fine Sand	...	...	0.001
Diatoms	...	...	0.00005
Clay	...	...	0.0000002

In the formula given above please assume the average head causing flow of water to sub-drain as equal to $\frac{1}{2} h$.

Conclusions.—The study reveals the following salient features :—

1. Subgrade soils provide a large variety of support differing in intensity from *high* to *low*, in character from *firm* to *elastic* and in uniformity from *constant* to *variable*.
2. Character of support depends on soil constituents, on soil structure and on field conditions.
3. Intensity of support in uniform subgrades depends upon cohesion and internal friction, the area of load distribution and the weight of the superimposed road crust.
4. High cohesion or high internal friction, or both combined, is needed for high subgrade support. Stiff clays have high cohesion, while sands have high internal friction. Clay loams and sandy loams combine high cohesion and high internal friction according to their composition.
5. The greater the internal friction, the greater will be the improvement, extended to the subgrade by the distribution of load over a large area, or by increasing the dead weight of the superimposed crust.
6. Side drains constitute an important feature in road construction.
7. Do everything possible to prevent water from entering the subgrade from the sides as well as from the surface of the road.
8. Subgrades are improved by adding clay to sand, sand to clay and both sand and clay to silts.

DISCUSSIONS ON PAPER N.

Mr. S. R. Mehra (Punjab) :—I have agreed to introduce Mr. Breadon's paper for him but probably for want of time Mr. Breadon has not been able to get in touch and discuss the paper with me, so that I do not know what the precise object of writing this paper is. Consequently I am not in a position to say very much by way of introduction.

One thing, however, I should like to point out on Page 2, fourth and fifth lines from the bottom. It seems there is some mistake in this case as silt is a non-plastic material. It is quite possible that by "silt" the author means that stuff which comes through the 200 mesh sieve, being a mixture of silt and clay.

Mr. S. G. Stubbs (Chairman) :—I wish to say a few words in introducing Mr. Breadon's paper. Mr. Breadon has carried out road-grading in the district of Bilaspur, Punjab, for the last ten years and the soil there is of a gravelly nature; it particularly lends itself to road-making. I presume Mr. Breadon's object in writing this paper is to pursue the subject a little further. He has got quite successful results with road-grading up to date. Presumably he wishes to improve the soil in his District in order to get still better results.

There are two names of gentlemen who wish to make observations on this paper. One is Rai Sahib Fateh Chand and the other is Mr. Dildar Hosain. I should like Rai Sahib Fateh Chand to speak first.

Rai Sahib Fateh Chand (United Provinces) :—The author in his conclusions says: 'Do everything possible to prevent water from entering the subgrade from the sides as well as from the surface of the road'. I agree with the author if he means thereby that both the surface and the subgrade should be protected against water damaging the same by its penetration through the surface or flowing across the subgrade washing away any portion thereof. But the presence of moisture in the subgrade or in its close proximity is definitely useful in maintaining a strong base by preventing disintegration of the soil.

I was very fond of raising my roads to keep the surface dry at all times of the year up to 1927, when I went to the Punjab to see the road graders at work there and came across a note written by the Secretary to the Board of Communications of that Province. In this note the said officer had greatly stressed upon the point of avoiding unnecessary raising of the surface above the ground as the moisture in the soil helps the stabilization of the road surface a great deal. On my return to the United Provinces I stopped raising the roads except where water stagnated or overtopped the road surface and found that the original surface was at least twice as good as the raised one. On the same type of soil and for the same traffic and weather conditions the number of patches noticed on the original surface were only one half to one third of those noted in the raised surface. This experience has been further confirmed during the past 12 years and I have

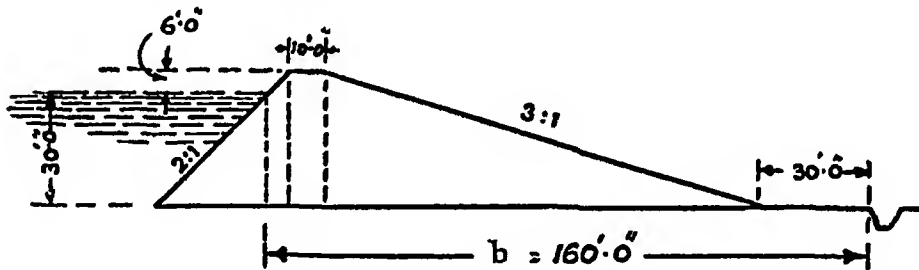
noticed that roads where the soil had moisture in close proximity stood much better than those in high embankments.

While, therefore, I agree with the Author that the water should not be allowed to *displace* any portion of the surface or subgrade, I hold that the subgrade should not be wholly deprived of the moisture which is very helpful in stabilization of the soil.

Mr. Dildar Hosain (Hyderabad-Deccan):—The formula given for determining the rate at which water travels through the soil to sub-drain is

$$V = K \cdot \frac{h}{2b}$$

I suppose H is a misprint for h in the symbols. Here the value of K for permeable soils such as loam, soft or hard moorum is not given. It is also not known whether the value of K for clay is given for the soil in the natural state or whether it is applicable to the case of road embankments, but it is presumable that the value refers to the soil after it is excavated and used for the road. Applying the formula to the case of a high embankment over which a road passes, as for instance, some of the roads which pass over tank bunds in the Deccan and South India, and taking a hypothetical case where $h=30$ feet we get the following result:



$$\begin{aligned} h &= 30 \text{ ft.} = 900 \text{ Cm.} \\ b &= 160 \text{ ft.} = 4800 \text{ Cm.} \\ \therefore V &= K \cdot \frac{450}{9600} \end{aligned}$$

Now assuming that the value of K for mixed soil as in the case of tank bunds is an average between Diatoms and clay, i.e. .000,025, V works out equal to .000,001,2 centimetres per second. But it has been observed in the case of bunds provided with base drains, that it is about $\frac{1}{2}$ foot to 1 foot per second. If the values as given represent the actuals, it would mean that the embankment is anything but permeable and conditions might arise when there would be either a slip or a settlement.

It is not known whether the formula has been evolved from some experiments, and whether the values of K should not be further investigated so as to be applicable to a wide range of soils.

It would be interesting to know whether V is the average velocity of permeation or that after permeation is complete.

Mr. Syed Arifuddin (Hyderabad-Deccan):—We have had a very interesting paper on chemical and physical properties of soils. It is worth while to conduct these experiments on various types of soils suitable for road making and determine the limits of various properties for soils suitable for subgrades and for surface. It is only then that practical advantage will be obtained from the knowledge of this nature. I feel that it will be interesting to know the effects of mixtures of various soils on the properties mentioned in the paper and their corresponding improvement for road construction.

There is one point about which my observation differs from the author's. He has stated in his paper that a certain amount of increase of volume takes place when a moderate amount of water is added to sand and then when the point of saturation is reached by the addition of more water the wet sand reverts to the original volume of dry sand. I have tested this point many a time but I did not notice any bulking of sand and subsequent shrinkage to the original volume; on the other hand I always noticed that after the saturation point is reached and a layer of water was allowed to stand over the top surface of sand the volume decreases below the volume of dry sand. I attributed it to the lubricating effect of water which reduced the friction and caused the sand to settle. On account of this fact I had to insist on profusely watering and tamping the sand foundations of some of the buildings by which the volume was reduced by nearly 25 to 30 per cent of the original volume of dry sand. I would like to know whether the experience of the author can throw some light on the different behaviours of sand in the matter.

Mr. S. K. Ghose (Bihar):—I decided not to open my mouth but have at last found it necessary to say a few words in this connection.

I think the author should have given us some information about the most important books in which we could find original standard references on the subject under consideration. I find that there are certain inaccuracies. The grain size for silt is given as 0.005. The grain size for fine sand should be .05 minimum, and not 0.1. Of course you may say what is the good of this juggling with figures; but if we are to carry out the soil experiments throughout India,—not only in the Punjab,—we should try to settle down to a practical basis and grade our soils according to certain definite standards as established by the American Bureau of Standards Testing of Materials. When I wanted to start soil experiments in relation to this line I found that I could not get standard sieves in India; they were only available readily from America. I think that the Indian Roads Congress would do a good thing if they could arrange for standard sieves by means of which experiments could be carried on in the Provinces. I think only one set of experiments carried on in the Punjab will not do for the whole of India.

In Page 2 (n) I find the question dealt with regarding liquid limit, the plastic limit and the plasticity index. The moisture equivalent dealt on page 3 (n) is not very clear. At least I cannot understand it. Then there are certain repetitions at the bottom of page 5 (n). It is written that "in the case of sand a certain amount of bulking does take place when a moderate quantity of water is added to it. This spreads in the form of a thin film over the sand particles and pushes them slightly apart, but this volume again reduces when the point of saturation is reached and the

voids are filled. Thus wet sand reverts to the original volume of dry sand". The same thing is repeated at the bottom of page 6 (n), but the explanation of the phenomenon is not given.

Mr. Mehra (Punjab) :—I shall reply to the points raised in connection with Mr. Breadon's paper.

Rai Sahib Fateh Chand expressed that according to his experience of earth roads, the presence of a lot of moisture in the subgrade was beneficial rather than otherwise as stated by Mr. Breadon.

Whereas this is true in the case of unmetalled roads due to the ease with which they can be repaired it is not so in metalled ones and it is to the latter category that Mr. Breadon's remarks apply. In metalled roads, too much moisture in the subgrade would soften the clay soils through capillary action and by causing unequal settlement under travelling loads will result in depressions and corrugations in the metalled surface.

Mr. Dildar Hosain queried whether the capital H in line 6 page 7 (n) was a misprint for small h. This is really so. He also asked whether V represented the mean velocity of flow through the soil. I am afraid this will have to be referred to Mr. Breadon. Syed Arifuddin said there was no bulking in sand. Bulking definitely occurs in loose sand under manipulation with change of moisture. There is no bulking, however, in undisturbed sand and this is I think, what Syed Arifuddin is referring to.

Mr. Ghose referred to the confusion in particle sizes of sand, silt and clay. These sizes are entirely arbitrary and are different in the case of different workers. In America they have tentatively standardised these sizes. Individual workers would be well advised to select any one system and stick to it, so that they can easily compare and correlate their results.

Mr. Ghose said that he did not understand what plasticity index was. It is the numerical difference between the liquid limit and the plastic limit which both can be determined by simple experiments described in my paper.

CORRESPONDENCE.

Comments made by Mr. F. L. D. Wooltorton, Executive Engineer, Shwebo, Burma, by post, on Paper No. N.

The author deserves the thanks of Road Engineers for his simple exposition of some of the fundamentals of Soil Mechanics though many of them will doubtless be disappointed that a Bibliography does not accompany the Bibliographical Study. The Congress is also to be congratulated on promoting interest in Soil Mechanics by publishing this preliminary information. The paper is believed to be one of the first or perhaps even the first in Soil Mechanics to be published in India. It is hoped that it will be received with the interest it rightly deserves and be the fore-runner of further papers and perhaps even of controlled research,

The paper is an elementary one as indeed is at the present time most suitable—and as such leads to little direct discussion.

Perhaps a few general remarks will be permitted.

From the paper it might appear that Soil Mechanics has been reduced to a series of mathematical formulæ. Such an impression must be carefully guarded against. Soil Mechanics or, in particular, the Study of Soils in Relation to Roads, is a very intricate subject embracing many branches of science and including their respective specific problems, some of which are referred to in a paper entitled "Soil Mechanics" appearing in December issue of 'Indian Roads'. Soil Mechanics, perhaps more than any other subject, illustrates that the various branches of science cannot be divided into water tight compartments.

Many soil chemists will agree that the Soil is the last of creations products to be treated mathematically. Its study requires considerable and wide knowledge and perhaps more sympathy and understanding. It is a living subject chemically active and continually changing. It cannot be considered as inert sand, diatoms or mica separately as might be. The life stream of soil consists, in part, of moisture movement containing salts in solution with its attendant transpiration or moisture in vapour form. It is on this life stream that the properties of soil directly or indirectly depend—its permeability, cohesion, etc. In tropical and subtropical areas these properties may vary from month to month as the direction and amount of moisture movement varies, though to what extent is not yet known.

The author seems to have fallen into the common error regarding "Colloids".

Strictly speaking, there may be very little true colloidal matter, whether in a sol or a gel form, in the mechanical fraction called colloid. This fraction is more accurately designated as that having certain colloidal properties. Part of this material having colloidal properties consists of fundamental clay minerals, or mixtures of clay minerals, depending upon the weathering process to which the soil has been subject in the geological past. These minerals when pure or soil colloids when impure are incorrectly described as uncrystalline. X-ray examination has proved that many are crystalline with a definite crystalline lattice structure. As regards the rest, information is not yet available.

Cohesion has not received the prominence it deserves and members of the Congress are referred to Terzaghi's "Principles of Soil Mechanics", Engineering News Record, Vol. 95, No. 19, November 5, 1925 and the Proceedings of the International Conference on Soil Mechanics and Foundation Engineering, Harvard, 1936.

The author has some very interesting remarks to make on the very important soil property of shrinkage limit and I would be very pleased to hear from what source these were obtained.

The connection between the shrinkage limit and the "heaving" referred to in the paper is believed to be a very real one and will be discussed with data in a paper under preparation by me.

The author has given a table showing some connection between the plasticity of a soil, its liquid limit and its shrinkage limit. I believe that this should be used with considerable caution. The table may hold for certain soils formed under some particular system of weathering but data at hand does not seem to bear out the correlation for the tropical soils examined by him.

In conclusion, one final word on the practical application of Soil Mechanics. It has been frequently stated that designed stabilized surfaces should not be less than 4 inches in depth and that they are unsuitable for cart traffic. I have constructed stabilized surfaces utilizing calcium chloride and Liquid Asphalt No. 2 of only $2\frac{1}{2}$ inches thickness which have withstood exclusively cart traffic and recommend the study of this application of stabilization to the design of Cart Berm Roads.

Note:— A reply to the discussions could not be obtained from the Author.

PAPER No. O.

THE USE OF SOIL STABILIZATION IN UN-METALLED AND 'METALLED ROADS IN INDIA.

BY

SITA RAM MEHRA, Assoc. M. Inst. C.E.,
Sub-Divisional Officer, Public Works Department, (Buildings and Roads),
Lahore (Punjab).

During the writer's recent extensive tours through the various countries of Western Europe, made with the object of studying the modern developments in highway engineering, the writer was particularly struck with the importance that was being attached to the role played by soil, in all kinds of highways, as a consequence of which, the subject of soil mechanics was receiving great attention every where.

Well equipped soil laboratories under the direction of soil engineers already exist in England, Germany, France, Switzerland, Sweden, Norway, Holland and Italy, and are being fast equipped in Belgium, and other smaller countries. And as it is generally felt, that the present knowledge of the engineering properties of soil is far behind the times, there is feverish activity in soil research, to be observed in almost all the countries.

In the case of Indian roads, although the great importance of soil mechanics is obvious on account of the very large mileage of soil roads, the subject has unfortunately been so far ignored by our engineers generally. The time is long overdue, that a systematic study was made not only of the soil as such but also of its behaviour on the road. It is with the object of presenting before the Indian Roads Congress for discussion, some of the writer's ideas and experiences, with regard to the economic use of stabilized soil in the construction and maintenance of Indian roads, that this paper has been written.

The writer's conception of a stable soil is that which, like concrete, has got its requisite quantities of coarse material, its filler and its binder. The coarse material in the form of sand, provides internal friction and hardness; the filler, in the form of silt provides embedment for sand grains; and the binder in the form of clay, coats the surface of silt and sand and provides cohesion, due to its natural stickiness. This cohesion is further augmented, by the surface tension of the thin films of moisture covering the various particles.

The reason why under similar conditions, some soils behave better than others, is that they have a better proportioning of the three constituents enumerated above. It is generally agreed that the ideal proportions are, clay 5 to 10 per cent, silt 10 to 20 per cent and sand 70 to 85 per cent, for normal conditions of moisture. The quantity of clay has to be correspondingly increased in unusually dry areas and decreased in unusually wet ones.

Our existing methods of construction and maintenance of unmetalled roads do not take into consideration, the economic possibilities of improving deficient soils. A very popular practice is to give a clay "topping" over sandy reaches. Leaving alone the expenditure part, it is not at all a complete remedy, because clay is as bad for traffic in wet weather, as sand is in dry weather. Again, looking at it from the economic point of view, it would be far cheaper to mix the required small quantity of clay to the sandy soil than to cover the whole thing up with imported stuff. It would also result in a much more stable mixture, which, besides being more durable and less expensive to maintain, will rank far closer to "all weather" road than the clay topping.

Similarly in reaches where the natural soil is too rich in clay, it would appear advisable to add the requisite quantity of sand, if available within reasonable distance.

Where the necessary material is not economically available, the use of bituminous emulsions, or cement or lime could be considered.

To the earth berms of the metalled roads, having a narrow width of metalling, the same remarks apply as to unmetalled roads. Besides eliminating a great deal of the dust nuisance in dry weather and the mud nuisance in wet weather, along with the risk to human life and property involved in both, it would be far cheaper to maintain the berms, if the soil is stabilized.

Still another use of stabilized soil, could be made in the construction of the metalled portion of the road or in widening the existing metalling in as much as, the brick on edge soling used in water bound macadam could probably be replaced by stabilized soil at about one fourth of the cost.

Recent experiments carried out by the writer have shown that it is possible to water-bind the metal directly over stabilized soil foundation but it is too early yet to say, whether it will wear well.

But the recommendations made above, can only be usefully employed if a systematic laboratory analysis of the soil and the available admixtures is carried out. It would also appear necessary to study by observation and local enquiries the behaviour of the soil in the field and to collect data regarding weather conditions. This is what was done by the writer in carrying out the stabilization experiments described in this paper.

So far as the laboratory examination of the soil is concerned the following simple tests were considered to be sufficient :—

(A) *Mechanical Analysis*.—Whereas until a few years ago, the terms sand, silt and clay were used in a very vague sense, modern research in America, has tentatively standardised the definitions of these terms, based on particle size, which are fairly accurate for practical road purposes. The definitions are as follows :—

Sand.—The material which passes through No. 10 sieve but is retained on number 200 sieve (A.S.T.M. Sieve numbers)

Silt.—Particles between 0.05 and 0.005 millimetre diameter.

Clay.—Particles finer than 0.005 millimetre diameter.

Sand was separated out by sieving through a 200 mesh sieve. The fraction passing through, was a mixture of silt and clay. There are various

methods of determining the percentage of clay in this mixture, viz, the pipette method, the hydrometer method, elutriation etc., but all of them are too laborious to be adopted by the average engineer, who has to do his own laboratory work.

An idea of the quantity of clay in a soil can be obtained from its Plasticity Index, which is an indication of the cohesive properties of the soil sample, being the range of moisture content within which the soil remains plastic. Consequently this method was adopted.

The Plasticity Index of a soil is the difference between its liquid Limit and its Plastic Limit. The last two soil constants were determined by the following simple laboratory experiments, which have been adopted as Tentative Standards by the American Society for Testing Materials.

(B) *Liquid Limit*.—About 30 grammes weight of the pounded soil passing the number 40 sieve (A.S.T.M.), was taken in a 4 inch porcelain dish and thoroughly mixed with gradually added water, with a spatula, till it became pasty. It was then smoothed off and grooved into two portions with a special grooving tool of standard size. Holding the dish firmly in the right hand, with the grooves parallel to the line of sight, it was lightly tapped horizontally against the palm of the other hand ten times. If the lower edges of the two soil portions just flowed together after ten strokes, it was taken to be correct moisture, otherwise a little more water was added and the process repeated. A small portion of the wet soil was weighed and dried in an electric oven at about one hundred and ten degrees centigrade and weighed again.

The Liquid Limit was calculated from the following formula :

$$\text{Liquid Limit} = \frac{\text{Weight of wet soil} - \text{Weight of dry soil}}{\text{Weight of dry soil}} \times 100$$

Photograph 1 shows the experiment before and after the closing of the groove.

(C) *Plastic Limit*.—About 15 grammes weight of the pounded soil passing the number 40 sieve (A.S.T.M.), was mixed with a little water till it could be easily rolled into a ball. The ball of soil was then placed on a glass plate and gently rolled on it, with the palm of the hand, into a long thread $\frac{3}{8}$ th inch diameter. If the soil did not crumble just before the thread reached this thickness, the soil was kneaded into a ball again and the process repeated. If it crumbled long before, some more water was added till it just crumbled at that diameter.

The crumbled pieces were weighed, oven dried at one hundred and ten degrees centigrade, and weighed again. The Plastic Limit was calculated from the following formula :

$$\text{Plastic Limit} = \frac{\text{Weight of wet soil} - \text{Weight of oven dried soil}}{\text{Weight of oven dried soil}} \times 100$$

Photograph 2 gives an idea of the experiment.

The experiments were carried out recently on the unmetalled road between Kabirwala and Sarai-Sidhu in Multan District, (Punjab). Two sites were chosen, one in mile 29/1 having a soil rich in clay and the other in mile 29/3, rich in silt and sand. The first was called soil number one and the second soil number two,

6 (o)

The wet soil was compacted into a metal container 2 inches cube, in three layers, the compaction being done by dropping a hammer from a fixed height ten times. The top was struck off and the cube weighed. The dry weight of the soil in the cube was determined as follows:—

Let total weight of soil + water $= W$

Weight of cube $= W_1$

Total weight of water in soil $= W_2$

then weight of water in soil cube $= W_2 \times \frac{W_1}{W}$

and therefore weight of dry soil in cube $= W_1 - \left(W_2 \times \frac{W_1}{W} \right)$

The experiment was repeated after adding more water each time, till the dry weight of the soil in the cube after rising to the highest figure began to fall. The moisture content at the highest figure gave the optimum moisture. The figure for water to be actually added in the field was of course obtained after deducting the hygroscopic moisture from the total.

In the actual execution of work it was found that this quantity had to be slightly increased during the hot afternoons due to excessive evaporation.

Mixing of water.—Water was gradually added by means of watering cans, to ensure uniform distribution (Photograph 4), and mixing was done by turning over the soil with a spade as the watering proceeded. Towards the end, a few men rubbed the soil between their hands to break up clods etc.

Compaction (for lengths 2, 3, 4, 7, 8, 9 and 10)

Ordinary rolling does not compact a fine soil to a depth of more than a couple of inches, if that. In order therefore to get the maximum possible densification, a special type of roller called the sheep's-foot roller (Photograph 5) was used. The projecting feet of the roller have a hammering effect on the soil, and compact it in layers by first going right down to the bottom of the soil (Photograph 6) and then, as the soil gets compacted from below, going less and less into it, till at last when the soil is fully compacted, they do not go in more than a fraction of an inch (Photograph 6). The roller was manufactured locally. The wheels on the top side are meant to carry the roller from one place to another.

The surface was finished off with a one-ton roller.

Addition of salt, lime and Oil.—

Salt was added in the form of salt water.

Lime was added in the form of lime water.

Oil was mixed with water, and though it kept floating on the top, a more or less uniform distribution was obtained, by keeping it stirred all the time.

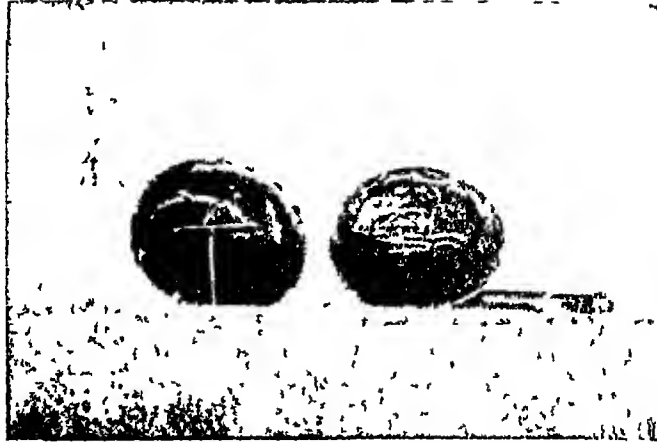
Conclusion.—Whatever the comparative economic value of the various methods of stabilization dealt herein may turn out to be, it is a foregone conclusion that soil stabilization can definitely be made an economic success, if systematically dealt with.

7 (o)

It is not too much to hope, that within a few years, with the systematic use of soil stabilization, the cost of maintenance of the unmetalled parts of our roads, will come down considerably in much the same way, as that of the metalled portions has, with the use of surface treatment. And also that the construction of metalled roads will be much cheaper with the increased use of soil stabilization.

The time is not far when each road will have its soil survey map, showing the properties of the soil, in its various lengths, and the position and the properties of the nearest available admixtures, along with instructions for the road gangs for stabilizing the soil before ever putting it on the road.

8 (o)



No. 1. Liquid Limit Test.

Showing soil with groove open and closed. Grooving tool is on the right.



No. 2. Plastic Limit Test.

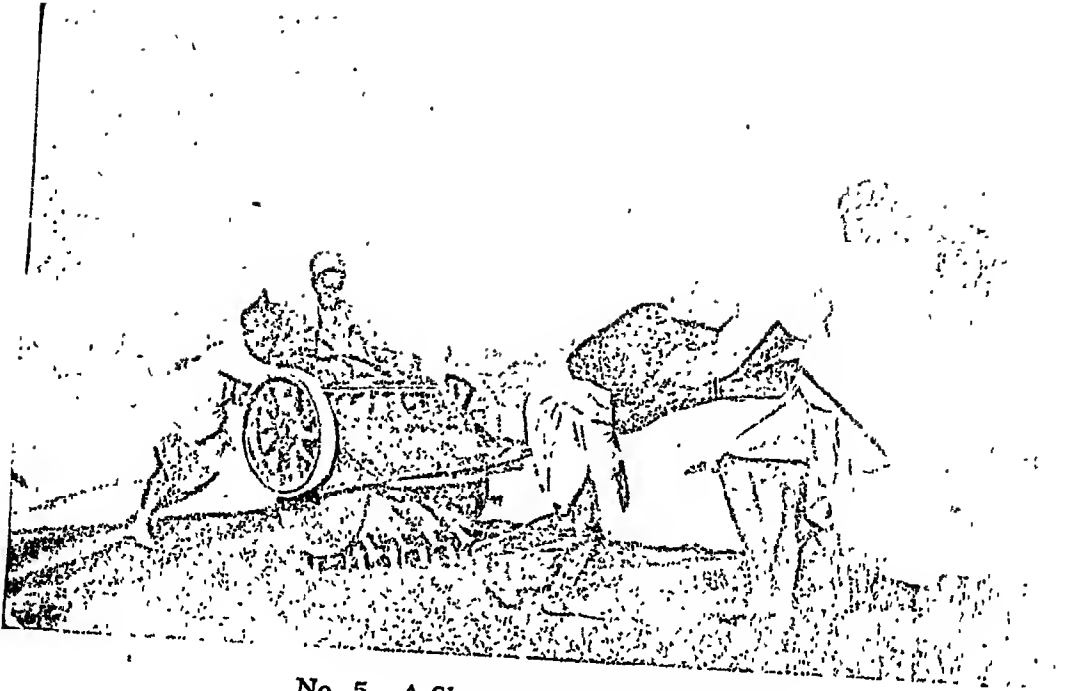
Showing the soil being rolled and the crumbled $\frac{1}{8}$ th inch soil thread.



No. 3. Showing the spreading of soil to required thickness.



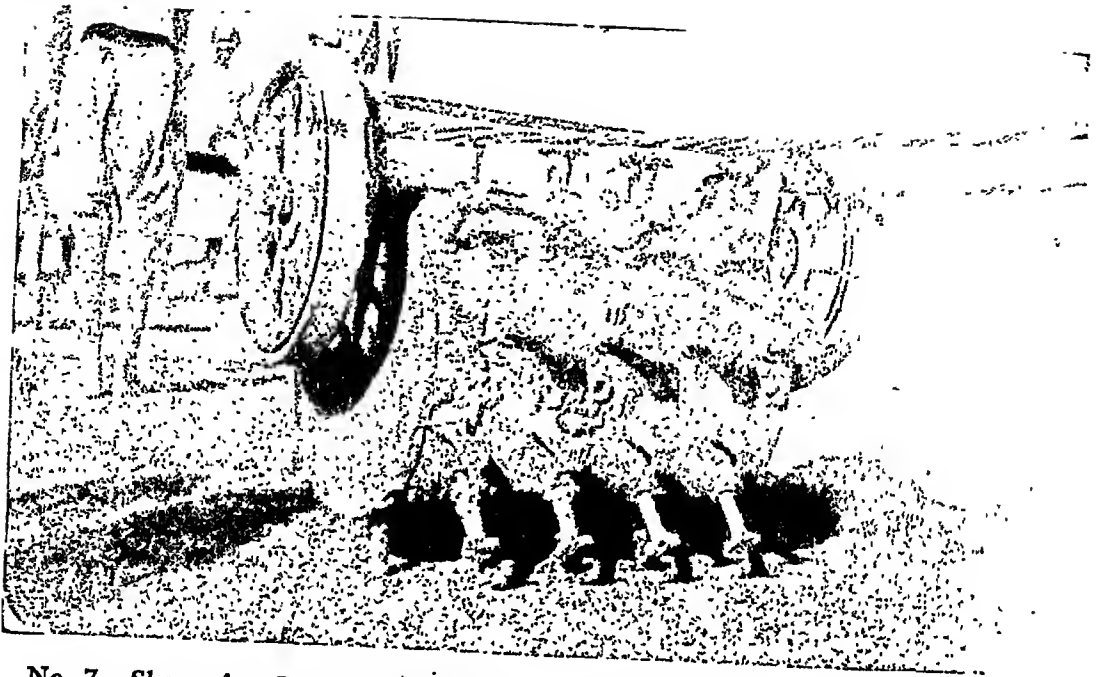
No. 4. Showing addition of water, spade mixing and hand mixing.



No. 5. A Sheep's foot Roller working.



No. 6. Sheep's foot Roller in the beginning of the operation, with its feet going right down into the soil



No. 7. Sheep's foot Roller towards the end of the operation. The feet do not go deep into the soil any longer.

DISCUSSIONS ON PAPER No. O.

Mr. Mehra (Author):—The idea that led me to start the experiments described in my paper was, that we need to evolve from first principles, a technique of our own, for the stabilization of soils, in connection with low-cost roads. The problem of low-cost roads in this country is very difficult on account of the diversity of traffic to be coped with and the paucity of funds available for roads. It is therefore that we must move slowly and carefully in this direction, in order not to lose sight of anything that may, even to a small degree, help us in finding a cheap solution to our great problem; this line of action has been followed in this first set of experiments.

The cost of these experiments has been rather high for the following reasons:—

- (a) The work was new to the workmen and was carried out under strictly controlled conditions.
- (b) The process adopted for the mixing of water was rather laborious. In practice, it should be quite enough to uniformly spread a requisite quantity of water over the levelled layer of soil and to leave it to soak through, overnight. By next morning, the water will have spread itself fairly uniformly through the whole depth, so that the soil will be fit for rolling. This item alone will reduce the cost by about 20 percent.
- (c) The quantity of water was carefully controlled by measurement, to give optimum moisture. But, as a result of this set of experiments, the judgment of the road inspector in-charge was so well trained in a short time, that he was able to control the moisture in the next set of experiments without measurement, by just looking at the moist soil and by pressing it in his hand. The optimum moisture as determined in the laboratory was then kept as a general guide.
- (d) The common salt was purchased at market price. It should be possible to bring quarry rubbish, duty free, for next to nothing and to rail it at concession rates.

This set of experiments was laid in June 1938. The traffic density of this road is of the nature of about 35 tons a day and consists of motor lorries, motor cars, light bullock carts and tongas, etc. For 3 days during elections, the traffic went up to well over 100 tons a day.

Maintenance was purposely not done in order to test the road to destruction. There were two showers of rain in August about half-an-inch each time, which the specially compacted lengths resisted without softening.

The present general condition of the stabilised lengths after 8 months is rather dusty, but the wear is well under $1\frac{1}{2}$ inches. Most of the damage has occurred at the joints between adjoining lengths due to the sheeps-foot roller not having been able to compact the ends properly.

The usefulness of grading the particle size and rolling by sheeps-foot roller at optimum moisture has been conclusively brought out by comparing the behaviour of the various sections from time to time.

Lime has had no stabilizing effect on the soil, probably due to the presence of colloids.

Country oil in the quantity used has had no appreciable effect; to use much larger quantities would be uneconomical.

Length No. 4 in which common salt has been used is more compact than those without it, due to there being thinner films of moisture round the particles, and has consequently worn better. The quantity of salt used, viz. 1.5 percent, was not enough to help the retention of moisture in the soil for any length of time.

Length No. 5 behaved beautifully till I left the district in October, showing no signs of wear whatever. When I inspected it a few days ago, it has a lot of loose dust on it, which had probably blown in from the sides, because otherwise there should have been metal mixed with it. On removing this dust, the surface below was found intact, except for a few pieces of metal which had apparently been dislodged by the hoofs of animals. It is my belief that if this is surface-treated, it will stand a fair amount of traffic, and that this type of construction, if carefully done, could probably replace the much more expensive water-bound macadam, in course of time. The main factor which protects the metal from attrition under traffic vibration is the cushion of stable earth all round it, and that is why I think, it will be superior to the water-bound macadam when surface-treated.

I do feel that the results of these experiments, though not being in any way a solution of the problem, are yet encouraging enough to justify further pursuance of the problem, and it is in this direction that I would like the discussion to take place.

Rai Sahib Fatch Chand (United Provinces):—I wish to say that the author considers the proportion 5 to 10 percent of clay to be an ideal one. In the United Provinces, any soil with less than 30 percent of clay cuts up in no time by sugarcane or timber or other heavy bullock-cart traffic which in the case of soil containing over 20 percent clay and moisture forms ruts instead of average quantity of undulating holes and patches of varying depths. So far as I remember, in the Punjab as well, in his detailed note on the subject, the then Secretary of the Board of Communications considered that a much greater proportion of clay was necessary than that mentioned by the author. I should like to know from the author if he has since tried the experiment of 5 to 10 percent clay on any road under such heavy traffic, and if so, on what road, and with what results? If the experiment has succeeded, it will have far-reaching effects in the United Provinces, as the cost of cartage of clay would be reduced by 50 percent.

The author considers clay to be bad for traffic in wet weather. This is true for such portions of roads as contain clay in their natural condition or are low-lying or not well-drained. But clay when laid over sandy portions forms a particularly hard surface, matching in hardness with the surface

of a metalled road I have treated over 400 out of 560 miles of the roads under my charge with clay in portions where there was heavy sand and in no place complaint of any kind has been heard. Be it due to sand being blown over the surface of the clay road, and thus making it harmless to traffic during the rainy season, or to the absorption of water by the sand below or due to whatever reason, the result has in all cases been an exceptionally hard and useful surface throughout the year.

The only defect noticed in this system has been that, when broken up, the surface becomes most troublesome, resembling that of a badly broken-up metalled road, due to numerous humps caused by the wheels falling alternately on hard clay and sand. The remedy for this defect has also been found by giving a topping of $1\frac{1}{2}$ inches of sand, which increases the life of the clay surface and when laid over such surfaces as contain excessive clay in its natural condition, improves the surface in moist places as well. I have tried coal refuse with and without molasses, shingle, brick ballast, kankar tracks and numerous other such remedies in place of clay, but none of them has been found to be as economical and effective as laying earth containing over 20 percent of clay, except under unusually heavy traffic, where nothing but a metalled or pucca road will stand.

As regards stabilisation of the berms and foundations of metalled roads no amount of stabilisation of the soil has succeeded under heavy traffic. A startling example of this is furnished by the Calcutta-Burhanpur road, where due to heavy traffic, some portions were full of pounded dust as compared to nice green grassy portions noticeable on almost all other roads, in spite of the natural advantage of the presence of moisture in the soil on the former as much as on any other road.

Dr. A. N. Puri (Punjab):—I am sure you will agree with me when I say how thankful we are to the authors of these two papers for having introduced a very important subject. I wish to point out certain misconceptions that are likely to have arisen from these papers and which have become clear to me from the remarks of some other gentlemen on these papers. The average engineer has got no idea of what clay and silt are. That is why in one paper we find that silt is represented as plastic and the other as non-plastic. The various particles have to be defined, not arbitrarily but in relation to their diameter sizes. It shows you, however, that the problem is not so simple as it may appear at the surface. Again in the transmission constants of soils I can show you that a soil with a high transmission constant can be rendered practically impermeable to water by adding a small quantity of sodium carbonate to it. The clay is the same, but it has undergone a simple change in the surface reactivity and that has made all the difference. The way I have reduced the percolation from a very high value to almost nil shows you also that the problem is not a simple one.

I wish to emphasise that the subject should be approached from its fundamentals, it is no use making experiments in the field, putting this thing and that thing and trying to stabilise the soil on certain broad details that are given in some paper. The problem has to be studied with relation to the type of the clay, the climatic conditions and other environmental factors. Therefore, we must proceed from some laboratory experiments so that in the large scale tests in the field we know exactly where we stand. The results could then be watched in all its stages and the conclusions will be sound and not arbitrary. We must remember that a certain process may

succeed in one place and the same process may not succeed in another place. These failures are likely to be discouraging. Therefore, to avoid them one must start from a broad fundamental knowledge of the whole thing. These are the few preliminary remarks that I wanted to make.

I have been asked by Mr. Murarilal to read his comments. He says that :

"The author in his paper has entirely omitted the mention of a very important and cheap material which can easily be had in many parts of the country and can advantageously be used to stabilise the earthen berms of our metalled roads. This is kankar, which used to be the main road-making material before the advent of motor traffic. It is at any time cheaper than oils and cut backs, that are used in conjunction with soil and are better able to withstand the traffic. The cost of consolidating a mile of berm 16 feet wide with 3 inches thick layer of kankar will be in the neighbourhood of Rs. 2,000/- taking rate of kankar at Rs. 8/- per hundred cubic feet and Rs. 2/- per hundred cubic feet for consolidation. This amount compares very favourably with the experimental lengths Nos. 4, 5, 8, 9 of the author.

"Kankar does not require any introduction to the Engineers as its properties of cohesion and adhesion etc., are so well-known to them. It only needs a plea to come into its own and hold the same position in road construction that it did two decades ago.

"Still greater advantage of using kankar for stabilising berms consists in the fact that the berms so stabilised will provide an excellent base for grafting a skin of stone metal on it when widening the road."

These are his comments, and, if I may be permitted to add, this subject of kankar in road stabilisation is also under investigation in the laboratory (Applause).

Mr. Syed Arifuddin (Hyderabad-Deccan) :—The author in his excellent paper has classified soil as consisting of particles between .05 and .005 millimeters diameters and clay finer than .005 millimeters. According to this definition silt is nothing but fine sand as the particles are measurable. A practical way of defining clay is that part of the soil which can be washed out and what remains is sand or grit which can be graded into fine, very fine etc.; and we can standardize the sieve or the diameter of the particles in any manner we like. I have many a time determined the proportion of clay and grit in this manner. What we call silt is always found to contain clay and fine sand. I, therefore, think that it will be better to determine clay and fine sand separately instead of classifying them as one.

Having determined the proportion of clay and grit or sand separately and also having determined the percentage of various sizes of grit in soils we can experiment on them by adding pure clay or pure sand and determine the best combination to give the best results under various traffic conditions. We can then come to some practical and definite conclusions.

Mr. S. Bashiram (Punjab) :—It is universally agreed that the future of communications in a country like India with its enormous size and poor

finances lies in unmetalled rather than metalled roads. Metalled roads with all their amenities are essential for centres of population but they only touch the fringe of our problem. I must therefore congratulate the author of the Paper on his fine efforts in presenting this congress on the very first day with a paper which deals with the practical aspect of this problem. I myself lay no claim to a deep knowledge of the subject and my excuse to say a few words lies in the fact that I saw these experiments over a month ago and my observations may possibly place some further information at the disposal of the Congress.

The traffic on this road, which is unmetalled, is very light indeed and consists on an average of only 6 lorries, 4 cars and 2 bullock carts per diem. The experiments with soil No. 2 are, on the whole more satisfactory than with soil No. 1. The point to remember, however, is that the cost for a moderately successful experiment works out to Rs. 4,200/- per 16 feet mile which is as high as two-thirds the cost for the water-bound macadam surface.

I may also add that just before his transfer from the scene of these experiments, Mr. Mehra left instructions for certain other experiments to be carried out. The main idea underlying this set of experiments was to reinforce the soil with brick ballast, sand, lime or imported clay. As these experiments have been made on one berm only of a metalled road, they can very conveniently be compared with the surface of the other berm which has not been treated. These experiments have been found to be much more satisfactory than those noticed in the paper under discussion, but here again the mischief is that the cost is very high.

The subject is of very great importance to us and in my opinion all efforts in this direction are well-worth the trouble.

Mr. Lakshminarayana Rao (Madras):—Over two lengths, one 100 feet long and another 600 feet long of a village road, two experiments were made. One was a failure but the other was a little better—I won't say pure failure, but partial success.

The first 100 feet length of village road was treated with oil. Three drums of the cheapest grade of crude oil available in Masulipatam, were mixed with sand and the same spread to a length of 100 feet and a thickness of one inch. After a time, I found that the oil had evaporated and that the surface was not improved much.

The second experiment was conducted after harvest seasons. Paddy hay was very cheap and cost about Rs. 8 to Rs. 10 per acre. I purchased about Rs. 30/- worth of hay and spread it to a depth of 6 inches over a length of 600 feet and set fire to it taking care that the fire did not spread far. (Laughter) I am not a chemist and I do not know how the soil was changed. The fire was started at 10 o'clock in the morning and it was continued till the fire subsided. Water was then sprinkled on the surface so that the burnt ashes may not be blown away. It was found that the soil on the top was burnt to bits of clinker—not hard, but moderately hard—and presented a better surface. I deduce from this that repeated burning of the soil, yields better results. I wish to place these experiments before you, and hope to be excused for taking your time.

Mr. H. B. Parikh (Karachi):—With the advent of Lloyd Barrage Canals it is necessary to improve communications in Sind and there is a great cry from the public for improving the existing roads and constructing new roads where necessary. As we are not a rich province we have to be satisfied with earth roads for the most part and we are therefore very much interested in soil stabilisation.

We find from actual practice that some soils give a very good road surface. Samples of such soils and other soils which cannot stand-up to traffic were sent to Dr. Mackenzie Taylor and his advice for treating the latter soils so that they may prove satisfactory was sought. He suggested the use of Calcium Chloride and we tried it on a short length. The treatment improved the road surface. The only difficulty experienced was that the rubber tyres of the vehicles passing over it started taking off some soil from the road and the surface again became very bad. Unfortunately before we could treat the soil further, those in charge of the road raised it with the result that we had to try out the same treatment in another place.

The details of the experiments we have carried out will appear in a Special Soil number of "Indian Roads", which is going to be published shortly. You will find therein that we have tried out not only treatment with Calcium Chloride but that with Sodium Chloride and Molasses as well, which help to obtain a satisfactory surface.

Then there was the question of the cost of salt. As one of the members said, it will help to cheapen treatment if salt could be had cheaply. With this end in view, we have already approached the Government of India who are pleased to allow concession for salt used on roads by exempting it from duty. This has enabled us to get salt very cheaply.

Now after carrying out these experiments I found that in some places the surface behaved very well, but a little distance away from it, it was not behaving in the same fashion, and it was rather difficult for me to find out as to why there was so much difference. I started studying literature on soils but I found there was difference in the nomenclatures used with the result that different results of mechanical analysis were obtained for the same soil. Assistance of a soil physicist was thus obviously necessary.

In the meantime, Mr. Mitchell called me to Lahore where the matter was discussed with Drs. Mackenzie Taylor and Puri and it was felt that unless we had some liaison officer who was an engineer and who could correlate the results obtained in the laboratory and in actual practice, it was very difficult to obtain satisfactory progress in the research for soil stabilisation.

As a result I am very glad that Dr. Puri, has been interesting himself in the matter and Mr. Mehra has been appointed as a liaison officer by the Punjab Government. Dr. Puri visited Sind and took away some samples of representative soils. We have got a laboratory in Sind where we get the soils analysed. Dr. Puri suggested some improvements in the method of analysis in order to obtain results useful from stabilisation.

point of view. We shall therefore be able now to get all information properly and proceed on a more scientific basis.

As you know, the nature of soils varies to a great extent from place to place. There is therefore difficulty in classifying the soils. Again when the work is being carried out, the soil from the borrow-pits, which often differs from the soil on the original ground surface along the road, is put on the top of the road, and the original classification does not stand. So it is necessary that in the field we should have some sort of rough and ready method by which we could analyse the soils, find out what quantity of salt is necessary to be added etc., and in this connection help of a soil physicist is really necessary. If you yourself can analyse the soils you can find out quickly the necessary details required for stabilising them and you will be in a better position to judge the results of your experiments and understand why different soils behave in different fashions.

All this knowledge is necessary in order to progress satisfactorily in stabilising soils on our roads and I think it is necessary, as I hope you will agree that we ought to carry on the research work for a number of years before we are able to come to certain definite conclusions and are able to get certain definite lead from scientific methods.

Many methods, other than chemical treatment, for stabilising soils are advocated. Some advocate burning soil on the spot, others again advocate adding of cement. Some advocate treatment with asphaltic oils. In actual practice it is very difficult to know what we should adopt unless we know the different details of soils, and relative costs of different treatments.

As Dr. Puri just now said, in the road formula with certain coefficient, the coefficient can be entirely changed by adding certain salt which will make the soil impermeable. We may apply the formula in actual practice and may find that water travels at a certain velocity in the soil but at some distance away we may find that water does not travel through it at all and we may be perplexed in the use of the formula. This shows that it is necessary to tackle the problem in a scientific way.

I hope that this work of soil research will therefore be carried on until we come to certain definite conclusions on that aspect of the science which is very necessary for our work. As you know, with the advent of motor cars, the roads have great loads to carry and we have to find out some sort of low cost roads by which we can provide proper communications with the amount of money that can be made available and satisfy the cry of the public. At present we have got to choose only between an earth road with the soil available and a metalled road and there is no middle course to meet the demand of traffic which may not be so heavy as to require a metalled road.

In some places cement concrete trackways may suffice the needs of traffic but if the soil is such that it may get cut up under traffic, it is dangerous to have trackways unless the soil on the sides of it be stabilised. Also, with the advent of motor buses the side berms on metalled roads, 9 feet to 12 feet wide, get cut up very badly and it is quite necessary to

stabilise the soil in the berms. The bearing power of soils can be increased by stabilisation and the depth of crust to be provided can be reduced. Thus the soil stabilisation interests us from all such points of view and we must try out different methods till we make a success of the stabilising processes (Applause).

Mr. S. K. Ghose (Bihar) :—In this paper we should have been given a comprehensive bibliography to help other Engineers. I think in Paper No. O, there is a big omission. There is no mention of conditions prevailing in America; well-equipped soil laboratories are in existence in America and I think America should have gone before England. In Page 2 (o) there is mention of water-bound macadam. The author says, "Still another use of stabilised soil could be made in the construction of the metalled portion of the road or in widening the existing metalling in as much as the brick-on-edge soling used in water-bound macadam could probably be replaced by stabilised soil at about one-fourth of the cost."

But as my experience goes, at least in Bihar the brick soling is invariably laid flat with good reasons. I do not know if this is the case in other provinces. In page 3 (o) the standard test for liquid limit is given for experiments to be carried out at 110 degrees centigrade. I wanted to know if that was correct. 100 degrees might have been better. It would be very helpful if the design of the Sheepfoot earth roller as actually constructed by Mr. Mehra, were given.

Incidentally I may mention that very few books on Soil Mechanics are kept in the Roads Congress Library; it would be very good indeed if the Roads Congress could publish standard books on Soil Mechanics in India.

For the information of the members who may be interested in pursuing their studies I append the following Bibliography:—"Highway Design and Construction" by Arthur G. Bruce, International Text Book Company. Scranton, Pennsylvania.

"Soil Surveys for Highways" by F. H. Eno, Engineering Experiment Station Circular No. 33, Ohio State University, Columbus, Ohio, July 1936.

"Engineering Properties of Soils" by C. A. Hogentogler and C. A. Hogentogler Jr., 1937.

"Cohesion of Earth" by Professor William Cain, Transactions of the American Society of Civil Engineers Vol. LXXX (1916).

Mr. C. D. N. Meares (Calcutta) :—May I ask Mr. Mehra whether he has established any relationship between compaction at optimum moisture content and stability? I ask this, as I understand, the latest practice is to compact at slightly less than the optimum as one thereby obtains a higher stability and load-bearing capacity.

Mr. K. G. Mitchell (Government of India) :—I do think that, first and foremost, we should persevere with experiments. One of the speakers has referred to the cost of experiments carried out. But what could be done

otherwise? I do not think there is any other way. Something has to be done in this direction. In course of time we hope that if we can make improvements, as the result of experiments, money will be provided to implement the results.

Mr. Mehra (Author):—I shall now take up the points raised in connection with my paper. Rai Sahab Fateh Chand said that, according to his experience, about 20 per cent clay behaved best and not 5 to 10 per cent as mentioned by me on page 1 (o), last para.

Now, there is a lot of confusion among Engineers as to what clay is. The quantity of clay, as determined in a soil, would depend entirely on the method of determination. Further, in some soils clay exists in a flocculated state whereas in others it exists in a dispersed state. 10 per cent of clay in a sodium soil would bind it beautifully whereas the same quantity in a calcium soil may not be enough. This is due to the fact that in the former case the clay exists in a dispersed state and in the latter case, in an undispersed state.

I personally put no faith in the clay content as determined from experiment. I design my mixtures according to the plasticity index which is a measure of the range of moisture content within which the soil remains plastic and which gives an indication of the cohesiveness of the clay present. For unmetalled roads, I keep the plasticity index between 7 and 11 depending on the climatic conditions of the locality. It is kept low in wet regions and high in dry places.

Mr. Murarilal advocates the use of kankar. Whereas kankar has proved a failure in comparison with stone metal for metalling, its admixture with soils for providing frictional stability is under investigation as already pointed out by Dr. Puri.

Syed Arifuddin suggests that the clay content in a soil can be determined by washing off. The method is extremely crude and is very likely to lead to grave errors. It is not recommended at all as the results may be easily found to be out by a couple of hundred per cent.

Syed Arifuddin said that fine sand should also find a place in the classification of soil ingredients. Whereas the only correct way of representing a soil is by means of a summation curve, it is necessary that the technique should be made as simple as possible, so that the average engineer can carry out the laboratory work himself. So far as the earth roads are concerned, it does not appear necessary to go to those fine limits and, therefore, only three ranges of particle size have been adopted, viz. clay, silt and sand.

Mr. Bashiram said that the cost of experimental length No. 5 is too high, viz. Rs. 4200 per 16 feet mile. It is really so, but it must be taken into account that half this cost goes towards the price paid for common salt at market rates. The cost could be further reduced as suggested in my introductory remarks.

Mr. Lakshminarayana Rao referred to the burning of soils. This phenomenon is already under investigation by Dr. Puri and as soon as sufficient laboratory data is available an effort will be made to apply it to field conditions.

Mr. Ghose wanted to know why the drying of samples was done at 110 degrees centigrade. This is in order to be sure of driving out all the water from the samples. It is the standard practice. Mr. Ghose also wanted to know the cost of a sheeps-foot roller. The roller cost me about Rs. 200/—.

Mr. Moares wanted to know the relationship between stability and moisture content. He said that compaction at a little less than the optimum moisture would perhaps give maximum stability. Whereas for earth roads, which are not waterproofed by surface treatment, compaction at optimum moisture definitely gives maximum stability under varying weather conditions, the question needs further research in the case of soils to be waterproofed from above and below by surface treatment.

Mr. S. G. Stubbs (Chairman):—I ask you, Gentlemen, to join me in giving thanks to Mr. Mehra for his valuable paper and also to you for your most valuable discussions. I hope you will find in my address what we in this country require. We require thousands of miles of roads but owing to limited funds we can only metal a very few. Therefore, unless we devise ways and means for improving the existing earth roads, this country would go without having good roads at all.

We are gratified to hear that steps are being taken to improve earth roads on a scientific basis, but unless we all co-operate in the work that is being done, nothing important could be effected. The Government of India have contributed substantial sums for research in the work and Mr. Mehra has been appointed to bring together successful results of work done in various fields. I feel, if we work together, the time is not far distant when earth roads will be improved very considerably.

PAPER Q.

Mr. G. P. Bhandarkar (Chairman):—Unfortunately Mr. Radice is not here. I understand he is now in England. Mr. E. S. Kirk of Messrs. Braithwaite Burn and Jessop Construction Company, Ltd., will therefore present the paper for him. Whatever comments are made will be sent to him to England for reply and will be incorporated in the Proceedings.

The following paper was then taken as read:—

PAPER No. Q.

SURFACE TREATMENT OF CONCRETE ROADS WHEN OUTWORN

By

W. A. RADICE, V.D., B.A. (Cantab), A.M. Inst. C.E., M. Inst. I.E.

During the Fourth Indian Roads Congress held at Hyderabad (Deccan) in January 1938, Mr. L. B. Gilbert, then Consulting Engineer to the Government of India (Roads), brought to the Author's notice the question of outworn Concrete Roads, especially as in the United Provinces there were many miles of concrete road and the day would inevitably come when some sort of surface treatment would become necessary if any attempt were to be made to conserve as great a part as possible of the value of the concrete.

That a concrete road, even when the surface has disintegrated to such a degree as to render repairs no longer useful, has a definite value as a foundation, there can be no question. The problem is to discover the most economic and efficient means to utilise this foundation.

In this paper it is not proposed to discuss the comparative merits of possible treatment since the Author is unaware of what has been already thought, written and done towards finding and testing out a satisfactory surfacing. He has, however, some special information at his disposal, collected at some trouble and expense when he was engaged in assisting in the preparation of an alternative design for the New Howrah Bridge now in course of construction in Calcutta, which may be found useful to those concerned with the problem stated. The purpose of this paper is therefore to record the information and make it available to Members of the Indian Roads Congress.

The bridge referred to is a cantilever bridge with a central span of 1500 feet. In a structure of such dimensions carrying a roadway and footpaths 100 feet wide, every pound per square foot of weight saved from the dead weight of the roadway is of considerable effect on the cost of the superstructure as a whole.

During the work of investigating this important question it was discovered that in Pittsburg, U. S. A., the Smithfield Street Bridge, an arterial road and rail bridge in the centre of the town and carrying a very heavy traffic, had become too weak to carry the increased modern live loads. It was a question of either finding means to lighten the dead load or rebuild the bridge. After considerable study it was decided to remove entirely the old floor system and replace it by a new floor system entirely made of aluminium.

This floor consists of flat metal plates (just like the deck of a battleship) some $\frac{3}{8}$ inch thick laid direct on channels about 8 inches apart and supported by the cross girders, etc. On this smooth metal surface the surfacing is laid direct and is only $1\frac{1}{2}$ inches thick on the roadway. On the sidewalks the surfacing is reduced to $\frac{1}{2}$ inch thickness.

A letter is appended from the Chief Engineer of the City of Pittsburg, reporting on the behaviour of this surfacing and also full specifications for the surfacing for the roadway and footpaths, as actually laid.

2 (q)

It would appear that this surfacing, having behaved satisfactorily under some years of traffic when laid on a flat metal plate in such thin layers might be found to be a suitable surfacing material to lay on a worn out concrete road, if slightly modified as suggested in the Appendix.

Should any one interested like to try it out, a word of warning is necessary. Results are not likely to prove satisfactory if the surfacing is laid direct on the rough untreated surface of a worn out concrete road. It is essential that the surfacing be of uniform thickness and to achieve this all broken up and loose parts of the concrete must be removed carefully and the whole surface plastered dead smooth. No particular attention need be paid to secure specially good adhesion between the plaster and the old concrete, as the plaster being covered will not be exposed to mechanical action.

Whether this suggestion will prove useful or not, it is impossible to tell without trial. The facts, as ascertained and reported in this paper are offered for what they are worth and in order to provoke constructive criticism.

APPENDIX.

*Letter from the Chief Engineer, Department of Public Works,
City of Pittsburg, Pennsylvania, dated November 22nd, 1934.*

Your letter of July 18th, 1934, addressed to the Chief Engineer of the Department of Public Works of the City of Pittsburg and requesting information regarding the paving on the Smithfield Street Bridge has not been previously answered for the reason that we desired to have more experience with this paving before reporting on same.

We are attaching copies of the Specifications used for the sidewalk paving and for the roadway paving. The sidewalk paving is wearing excellently under traffic. The roadway paving, however, seems to be somewhat too rich in asphaltic content and the particle size of the coarse aggregate seems to be somewhat too small. As a result there is a tendency for this paving to push and crowd under vehicular traffic, particularly near the ends of the bridge where it is frequently necessary for rapidly moving vehicles to suddenly apply their brakes, thus exerting a drag on the paving.

When it becomes necessary to replace the paving the Department of Public Works will probably specify a mixture having a somewhat lower asphalt content and a somewhat larger particle size, in order to overcome this movement of the paving. In general, however, the paving has been very satisfactory and there has been no difficulty with adhesion between the metal plates and the asphalt surfacing.

The paving seems to perform equally well in cold and hot weather. During the last year Pittsburg has had temperatures varying from zero to ninetyeight degrees Fahrenheit and July and August were especially hot, averaging temperatures during the daylight hours in excess of seventyfive degrees.

COLD MIX SINGLE COURSE ASPHALT WEARING SURFACE.

Standard Specification for 1½ inch single course asphalt pavement on new aluminium roadway floor of Smithfield Street Bridge.

General.— This specification covers the construction of 1½ inch single course cold laid asphalt pavement on a new aluminium bridge floor.

Foundations.— Upon the foundation, consisting of an aluminium plate bridge floor, prepared in such manner as to produce a firm, unyielding surface, regular as to longitudinal grade and uniform, as to cross section, as specified by the Engineer, properly swept and clean, shall be laid cold asphalt pavement.

Pavement.— The asphalt pavement shall consist of a one course asphaltic mixture that has been proved a successful paving material by actual service under heavy traffic conditions for at least five years, spread and compressed upon the prepared foundation.

Thickness.— After it has received its final compression by rolling, the asphalt pavement shall have a minimum thickness of 1½ inches.

4 (q)

Mixture.—The formula used for preparing the cold asphalt paving mixtures shall be set to proportion them to the best advantage from the materials hereinafter specified, but not to exceed the following limitations :—

Materials:—

Broken Limestone .	...	...	83.0 to 90.0 per cent.
Liquifier	...	...	0.4 to 1.0 „
Asphalt Cement	...	...	5.0 to 7.0 „
Hydrated Lime	...	...	0.5 to 1.0 „
Mineral Filler	...	...	0.0 to 8.0 „

Broken Limestone shall be mechanically air dried and clean, tough, sound and durable, and shall be graded from coarse to fine, all passing a screen having circular openings $\frac{3}{8}$ inch in diameter and be retained on an eight mesh laboratory screen. Liquifier shall be a mineral oil the specific gravity of which shall be between 0.814 (42 degrees B) and 0.788 (50 degrees B) and which shall have a flash point of not less than 105 degrees Fahrenheit. Asphalt Cement shall be of such quality that it will meet all tests provided for asphalt cement, including the following :—

1. It shall be homogeneous and free from water.
2. The specific gravity at 77 degrees Fahrenheit shall not be less than 1.025.
3. The penetration at 77 degrees Fahrenheit shall not be less than 65 nor more than 95.
4. The ductility at 77 degrees Fahrenheit shall not be less than 50 centimetres
5. The loss on heating at 325 degrees Fahrenheit shall not be more than 3 per cent and the loss in penetration after heating shall not be more than 50 per cent.
6. It shall not flash below 350 degrees Fahrenheit open cup method.
7. It shall not contain less than 95 per cent bitumen.

The methods of testing shall be as follows :—

Specific gravity—	American Society for Testing Materials D70-27					
Penetration —	“	“	“	“	“	D 5-25
Ductility —	“	“	“	“	“	D113-32T
Loss on heating—	“	“	“	“	“	D 6-30
Flash point —	“	“	“	“	“	D92-94
Bitumen —	“	“	“	“	“	D 4-27

Hydrated Lime shall meet the requirements of the American Society for Testing Materials C 6-24.

Mineral Filler shall be clear crushed stone screenings, 90 per cent of which will pass an eight mesh laboratory sieve.

Mixing.—The materials specified above, in the proportions of the formula fixed, shall be introduced into each batch in the rotation and combined in the manner hereinafter set forth.

5 (q)

The dry broken stone, at a temperature not over 85 degrees Fahrenheit weighed out separately to the quantity specified, shall be placed in a twin pug mill and mixed until uniformly intermingled.

The liquifier measured in a calibrated device to provide the exact quantity specified, shall then be sprayed into the mixer, in such a manner that it will uniformly penetrate the surface voids of the broken stone and fully coat the surface thereof, and the mixing continued until the stone is thoroughly coated.

The asphalt cement, weighed in a special distributing bucket attached to a special scale equipped for quick adjustment, shall be poured into the mixer in such a manner and at such a temperature between 250 degrees Fahrenheit and 300 degrees Fahrenheit that it will uniformly coat the surface of the liquifier, impregnated and covered broken stone and the mixing continued until the batch presents a uniform black colour.

The hydrated lime, exactly weighed and measured, shall then be sprinkled into the mixer, in such a manner that it will be uniformly incorporated in the mixture, and the mixing shall be continued until the whitened mass has attained its former black lustre.

The mineral filler, carefully weighed, shall then be introduced into the mixer in such a manner that the particles will be uniformly spread throughout the mass by adhering to the liquifier-asphalt coated fragments of broken stone which form the body of the mixture, when the batch is completed and ready to be dumped.

Transporting.—Rail shipments shall be made in cars free from dirt and lightly sprinkled with sand or screenings, and the asphalt paving mixture shall be so loaded in tight vehicles, carts, wagons or trucks, previously cleaned of all foreign materials and delivered to the work, that it will not become contaminated in any way.

Laying.—The asphalt paving mixture shall be laid on a dry base, properly prepared and clean, and only when weather conditions are favourable.

The mixture upon arrival at the work, shall be deposited on the outside of the area on which it is to be laid, distributed into place and spread in a uniformly loose layer of such depth as will produce a finished pavement at least one and one half inches thick after compression rolling. The longitudinal grade and cross section shall be supplied by the Engineer to the Contractor who shall adhere strictly thereto in performing the work.

Rolling.—Adjacent to flush curbing, gutters and structures used as headers the mixture shall be spread uniformly high, so that when completed it will be slightly above the edge of said abutments. For a radial distance of eight inches round all structures and locations inaccessible to the roller, the compression shall be effected with a tamper weighing not less than 35 pounds.

The asphalt mixture, as soon after spreading as is convenient, or advisable, shall be compacted by rolling, at minimum speed, with a power roller weighing not less than 10 tons. The roller shall begin at the sides and travel longitudinally gradually moving towards the centre of the roadway by overlapping about one half the width of the wheels each trip.

Wherever, during the rolling, low spots appear, additional mixture shall be spread thereon and rolling continued until the surface is regular and of even texture.

SPECIFICATION FOR SIDEWALK SURFACING.

The sidewalks shall be surfaced with either an asphaltic mastic or with a cold process asphaltic paving as described below. In either case the surfacing must be capable of carrying foot traffic not more than ten hours after its application.

Asphaltic Mastic Surfacing.—The composition of the asphalt mastic surfacing shall be as follows :—

- (1) Hard flux approximately 6 per cent.
- (2) Asphalt mastic approximately 47 per cent.
- (3) Mineral aggregate approximately 47 per cent.

Hard Flux.—The hard flux must be of an approved asphalt base and have a penetration of 50 and a fire point of not less than 500 degrees Fahrenheit. It shall be delivered in the original drums or barrels.

Asphalt Mastic.—The asphalt mastic shall consist of a limestone rock asphalt, finely ground to pass a No. 8 laboratory sieve, unless some other mastic be approved by the Engineer.

Mineral Aggregate.—The mineral aggregate shall consist of clean, well screened limestone chips passing a No. 4 screen and clean fine sand, the combination being so graded as to reduce voids to a minimum.

Mixing.—These materials shall be charged into the mixing kettles in the order stated above viz., 1, 2 and 3. The flux and mastic are to be melted before the addition of mineral aggregate, and the combination is to be mixed until it is uniform and homogeneous. The temperature at no time shall exceed 450 degrees Fahrenheit and the temperature of the mixture when laid shall not be less than 325 degrees Fahrenheit.

Spreading and Laying.—Before applying the surfacing, the metal surface of the sidewalk must be thoroughly cleaned and be free from dust, dirt, grease, oil, moisture and loose particles.

Before laying the asphaltic mastic and immediately in advance thereof the surface of the sidewalk shall be given a mop coat of hot asphalt of an approved base and penetration to secure proper bond. The hot asphalt mastic surfacing shall then be spread over the mopped surface in a single layer so as to form a finished layer $\frac{1}{2}$ inch in thickness. Screeds shall be used to form the mastic to a true surface, and after spreading and as the hot mastic cools and sets, it shall be lightly sprinkled with hard white sand and/or cement and rubbed to a smooth finish with the usual smoothing tools or floats.

COLD PROCESS ASPHALTIC PAVING.

Composition.—The cold process asphaltic material shall be composed of the following materials :—

1. Aggregate
2. Filler
3. Asphalt Cement.

Aggregate.—The aggregate shall consist of sand or limestone screenings or a mixture of the two. The sand shall consist of clean, hard, durable grains, free from clay, loam or other foreign matter. The limestone screenings shall be free from weathered particles and the larger particles shall be free from adhering dust. All material shall pass the $\frac{1}{4}$ inch screen and conform to the following grading :—

Passing 200 mesh				0 to 25 per cent.	
„	80	„	retained 200 mesh	12 to 40	„
„	40	„	80	12 to 40	„
„	20	„	40	12 to 40	„
„	10	„	20	12 to 40	„
„	$\frac{1}{4}$	„	10	0 to 30	„

Filler.—The filler shall be thoroughly dry limestone dust or other suitable material as specified by the Engineer, the whole of which shall pass a 30 mesh sieve, and at least 75 per cent of which shall pass a 200 mesh sieve.

Asphalt Cement.—(a) The asphalt cement shall be used in two component parts, of which the first shall be a grade of asphalt hard enough to be reduced to powder in an impact mill, whilst the second part shall be a grade of asphaltic flux oil which is capable of complete amalgamation with the first

(b) The hard asphalt shall conform to the following requirements :—

1. It must be homogeneous.
2. Solubility in carbon disulphate, not less than 99 per cent.
3. Solubility in carbon tetra chloride not less than 95 per cent.
4. Penetration at 115 degrees Fahrenheit, 100 grams, 5 seconds : 5 to 15.
5. Penetration at 77 degrees Fahrenheit, 100 grams, 5 seconds : 3 to 5.
6. Melting point (Ring and Ball), 240 degrees to 275 degrees Fahrenheit.

The hard asphalt must be reduced to powder in an impact mill. As used, not less than 50 per cent of it shall pass an 80 mesh screen and 95 per cent shall pass a 20 mesh screen.

(c) The flux oil shall conform with the following requirements :—

1. It must be homogeneous and free from water
2. Specific gravity at 77 degrees Fahrenheit not less than 0.97
3. Viscosity Furol at 122 degrees Fahrenheit, 600 to 800 seconds
4. Loss on heat—5 hours, 50 grams, at 325 degrees Fahrenheit; not more than 5 per cent
5. It must not be capable of complete amalgamation with the hard asphalt.

(d) The flux oil and hard asphalt shall be of such characteristics that a combination between 45 and 55 per cent of either component will produce an asphalt cement of 70 penetration, and in the manufacture of the pavement they shall be mixed in such proportions as will produce when completely amalgamated, an asphalt cement of the penetration required by the Engineer.

8 (g)

(e) The asphalt cement in the pavement shall meet the following requirements for physical and chemical properties :—

1. Specific gravity at 77 degree Fahrenheit not less than 1.02
2. Flash point, not less than 347 degrees Fahrenheit
3. Penetration at 77 degrees Fahrenheit, 100 grams, 5 seconds : 50 to 80
4. Ductility at 77 degrees Fahrenheit not less than 15.
5. Loss at 325 degrees Fahrenheit, 5 hours, not more than 3 per cent
- 6 Penetration of residue at 77 degrees Fahrenheit, 100 grams, 5 seconds, as per cent of original penetration : not less than 50 per cent.
7. Total bitumen soluble in carbon tetra-chloride not less than 98 per cent.

Mixing.—(a) The aggregate shall be thoroughly dry and shall reach the mixer at a temperature not exceeding 110 degrees Fahrenheit.

(b) The flux oil shall be used at a temperature not exceeding 125 degrees Fahrenheit. The hard asphalt shall be reduced to a powder as above specified.

Grading.—The grading and composition of the mixture shall conform to the limits stated as follows :—

Bitumen soluble in carbon bisulphate				...	9 to 11 per cent.
Passing 200 mesh				...	9 to 19 "
"	80	"	retained on 200 mesh	...	10 to 33 "
"	40	"	" " 80 "	...	10 to 33 "
"	20	"	" " 40 "	...	11 to 34 "
"	10	"	" " 20 "	...	10 to 33 "
"	$\frac{1}{2}$	"	" " 10 "	...	0 to 24 "

Mixing.—The various components of the mixture shall be separately and accurately measured by weight for each batch to be mixed.

The limestone filler may be introduced, either partially or wholly, in conjunction with the pulverized hard asphalt. The mixture shall be made in an approved twin pug mill or other type of mixer satisfactory to and approved by the Engineer, by first charging it with the mineral aggregate including optionally the filler and adding thereto the weighed quantity of oil. The mixing shall be continued until every particle of the aggregate is entirely coated with the flux oil. At this stage a weighed quantity of the powdered asphalt shall be added, either alone or in combination with some or all of the filler and mixing shall be continued until the powdered asphalt is evenly distributed throughout the mix, when it will be ready for discharge from the mixer.

Cleaning.—Before laying the sidewalk plates shall be thoroughly cleaned and freed from dirt, grease and oil.

Laying.—Before laying the plates shall be coated with waterproof coating as hereinbefore specified, in two coats, to afford a satisfactory bond. The material shall be spread, by shovels, rakes or other approved spreading devices in a loose layer of such a depth that after compaction it shall have a depth of not less than $\frac{1}{2}$ inch. The material shall then be rolled with a hand roller weighing not less than 200 pounds and not less than 12 inches in length, until thorough compaction is secured. At points not accessible to the roller the mixture shall be thoroughly tamped with iron tampers. The finished surface shall show no variation from the general surface in excess of $\frac{1}{16}$ inch per foot ordinate of a ten foot straight edge, set upon the surface parallel with the path of traffic.

DISCUSSIONS ON PAPER No. Q.

Mr. E. S. Kirk (Calcutta):—Mr. Radice, who is now in England, is unfortunately unable to present his paper and I therefore have much pleasure in introducing the paper on his behalf.

I have no special remarks to make, but I would like to draw your attention to Mr. Radice's remarks in the last paragraph—"Whether the suggestion will prove useful or not it is impossible to tell without trial. The facts as ascertained and reported in this paper are offered for what they are worth and in order to provoke constructive criticism."

Arrangements have been made with the Secretary that any criticisms that are made will be forwarded to Mr. Radice for his replies.

Mr. G. B. Vaswani (Karachi):—We are thankful to the author, Mr. Radice, for obtaining these important specifications and collecting them at some trouble and expense.

We saw in Lucknow and Hyderabad (Deccan), miles and miles of cement concrete roads of various thicknesses. We were given to understand that the life of a cement concrete road should be reckoned from 25 to 30 years. According to the nature of traffic, the thickness of cement concrete was being reduced. At Lucknow, where surface painting would have sufficed, 3 inch cement concrete road pavement was being constructed so as to reduce the cost of cement concrete road when spread over 30 years and to compare well with the cost of asphalt pavements.

Our cement concrete roads are hardly few years old and on the above basis of 30 years life, they will require some time for renewal.

During the interval, the concrete experts would be able to find out how to retain in tact the surface of the cement concrete roads. Probably $1\frac{1}{2}$ inches to 2 inches thick pavement of rich mixture of cement concrete superimposed over the old road may suffice than providing any kind of asphalt or tar pavement.

The circumstances under which the asphalt pavement recommended by the Chief Engineer of Public Works Department, Pittsburg, was adopted, were quite different from the usual conditions met in India. In the case under reference every pound of dead load per square foot counted, and a new floor system, entirely made of aluminium, was adopted for the bridge construction. If the question of weight had not arisen, probably the Chief Engineer would have adopted cement concrete pavement for the bridge instead of $1\frac{1}{2}$ inch to $\frac{1}{2}$ inch thick pavement of asphalt.

Now I would like to take you to the specifications of the asphalt pavement. In Paras 2 and 3 of pages 3 (q) it is stated :—

"The roadway paving, however, seems to be somewhat too rich in asphaltic content and the particle size of the coarse aggregate seems to be somewhat too small. As a result, there is a tendency for this

paring to push and crowd under vehicular traffic, particularly near the ends of the bridge where it is frequently necessary for rapidly moving vehicles to suddenly apply their brakes, thus exerting a drag on the paving".

This shows that the paving which has been recommended has not been a success.

Further on it is stated that :—

"When it becomes necessary to replace the paving, the department of Public Works will probably specify a mixture having a somewhat lower asphalt content and somewhat larger particle size in order to overcome this movement of paving".

This shows that the specification recommended is not an ideal one.

On page 4 (q) it is stated that :—

"The penetration at 77 degrees Fahrenheit shall not be less than 65 and not more than 95".

The range of penetration is too wide. We generally specify penetration to 40, 60 to 70, 80 to 100, etc.

You cannot get the same results with asphalt of 65 penetration as with as 30 an asphalt of 95 penetration.

The pavement has been described as "Cold Mix", whereas on page 5 (q), para 3 reads as under :—

"The asphalt cement, weighed in a special distributing bucket attached to a special scale equipped for quick adjustment, shall be poured into the mixture in such a manner and at such a temperature between 250 degrees Fahrenheit and 300 degrees Fahrenheit...."

This makes it hot mixture and not cold mixture as shown in the heading.

I am, therefore, of opinion that we should leave it to the local experts of concrete, tar and bitumen to guide us as to what kind of treatment would be suitable for a cement concrete road in a particular locality, as they are in a better position to know the local conditions of aggregates and their behaviour in concrete and asphalt mixtures.

We cannot confine ourselves to one particular specification as local conditions vary at different places.

Mr. Brijmohan Lal (Punjab) :—The method of surface treatment of worn out concrete roads suggested in the paper under discussion appears impracticable for being adopted in the working conditions of this country. The methods of testing, weighing and mixing the different materials are too complicated for field work here. The cost per hundred square feet is also likely to be very high. In this connection attention is invited to a small note that appeared on page 187 of Indian Engineering for December, 1938 reproduced below :—

"Concrete Road Resurfacing.—Partly as an experiment a length of concrete road in Pennsylvania has been resurfaced with a 2 inches

layer of concrete by the Vacuum Process. This method was adopted in preference to the complete relaying of the road and it was considered that if a new concrete finish could be made to bind effectively with the old slab so that it became an integral part rather than an added but separate layer, a thickness of two inches was adequate".

In my opinion some alternative on the above lines would suit the Indian conditions better.

Mr. Dildar Hosain (Hyderabad-Deccan):—The author is to be congratulated for having made valuable contributions on the subject before the Indian Roads Congress. The subject is one of very great importance. In Hyderabad we have considerable milages of cement concrete roads which will become due for reconstruction. I would, therefore, like to put a few queries so that we may get the benefit of the experience of the members.

(1) It would be interesting to know whether the author can offer any suggestion as to how the aluminium floor system should be fixed on the old concrete base of a worn out road after it has been plastered and made ready, as suggested in the paper, keeping in view the effects of temperature.

(2) In the case of bridge flooring, while the introduction of aluminium will no doubt reduce the dead load so far as the decking is concerned, would it not imply the introduction of some stringers to secure the dispersion of live load because of the thinness of the flooring. This would mean that while the weight of the flooring is being reduced, the weight of the superstructure is being increased.

(3) It would be interesting to know if any members of the Indian Roads Congress have had an opportunity of trying the Vacuum Concrete Process, referred to in the Engineering News Record of December, 1935, October, 1936, and March 1937. That process consists of forcing a bond between the old and new concrete by atmospheric pressure (about 1500 pounds per square foot) brought into action by suction on special "Vacuum Mats."

Excepting for the initial cost of the vacuum equipment the process appears likely to prove cheaper in the long run.

Mr. D. Nilsson (Bombay):—It appears to me that the best method of repairing the worn surface might be by applying 1½ inches to 2 inches of new concrete by the Colloidal grouted process. For this broken metal only requires to be spread and lightly rolled and then the Colloidal grout is poured into this metal. Being generally of a 1 to 1 mix and therefore a very strong grout it will bond much better I think with the worn surface than would ordinary concrete applied thereon. I have however not been able to try this out myself but would suggest that if anybody has a concrete road requiring repairs they make an experiment as I think it would be both very satisfactory and economical.

Rai Bahadur A. C. Mukerjee (United Provinces):—As there is a fair mileage of cement concrete roads in the United Provinces, the problem of resurfacing of worn out concrete roads has been engaging our attention from some time. Several things have been tried but I am sorry to confess that so far we have not found any treatment which can be recommended definitely for adoption.

Broadly speaking there can be two kinds of surfacings one using cement as the binder and the other using bitumen for the purpose. Surfacing with cement as binder can, among other things, consist of cement mortar or cement concrete, while among bitumen surfacings are bitumen paint, premix carpets (hot or cold) or asphaltic concrete carpets.

We tried *Gunit*—i.e. cement mortar sprayed on to a damaged concrete road surface, under pressure so as to build up a layer 1 inch to 1½ inches thick. This could also be reinforced. It was not, however a success. It broke up under traffic and had to be taken up and removed.

Surface painting with bitumen was tried but failed in a short time under the iron tyred heavy traffic. In one section bitumen premix carpet about 1 inch to 1½ inches thick was tried but this too was not a success, although it did much better than surface painting.

As thin concrete slabs have been used with success in the United Provinces, I think that the only surfacing which may be used successfully on worn out concrete roads is a cement concrete slab about 2 inches thick or even 1½ inches thick, and reinforced if necessary.

Mr. S. G. Stubbs (Punjab):—The only solution of the problem is to lay either a thick bituminous carpet or another layer of concrete on a worn out concrete surface. If a thin bituminous carpet is laid on concrete, the aggregate is bound to be crushed and the carpet will fail.

Mr. B. N. Shenoy (Calicut):—It means that the surface has worn out to such an extent that resurfacing is necessary. There is no reason therefore why we should not make it up throughout with concrete of 2 inches thickness, with reinforcement, of course. In Madras Presidency water-bound macadam road is re-surfaced frequently to 2 inches thickness. That would be a real solution of the problem. You can preferably also use concrete, 2½ inches thickness. That should prove a better solution. Only, for 2 inches and 2½ inches thick concrete, we have to use smaller sizes of aggregate.

Mr. H. B. Parikh (Sind):—The carpet on the road on the Lloyd Barrage did not stand up to the strain of the traffic. In about two years time it had to be renewed. The reason was that it had got very hard concrete as the base below which was unyielding. I do not, therefore, think that any asphalt construction on a cement concrete road would prove successful.

Mr. D. Nilsson (Bombay):—Two speakers have just said that the resurfacing should be reinforced. If they consider that reinforcement is necessary I would suggest that ordinary reinforcing bars placed crosswise and lengthwise should not be used, but that instead hoop iron be used in the form of rings of about 21 inches or 2 feet diameter; the rings being spaced at about 3 feet or 4 feet centres.

With the hoop reinforcement the shrinkage of the concrete will be taken up by minute cracks between the hoops, these cracks being so minute that they cannot be seen and will not affect the surface. If ordinary reinforcement is used the re-surfacing may crack at longer intervals but that crack will then be of a more serious nature and be more difficult to deal with.

Mr. G. P. Bhandarkar (Chairman):—I am afraid some of the speakers have not been very fair to the author. The author says that he has some special information at his disposal. He has simply furnished the information

and has not laid down any specification to be adopted in India, for putting a new surface on cement concrete roads. I think he has done valuable service in introducing this subject.

We find that concrete roads have started well and it is time we considered some method of dealing with worn out surfaces. Concrete roads have generally a long life and are meant to stand bullock-cart traffic. They will need resurfacing, and it is a matter for consideration which material will stand bullock-cart traffic. In my opinion it is no use thinking about asphalt. We must have concrete to concrete. Whether it is going to be reinforced in any particular way, will depend upon the method we propose to adopt.

Gentlemen, I think you will join me in thanking the author for introducing this valuable subject at this session of the Indian Roads Congress.

CORRESPONDENCE.

1. Comments made by Mr. W. F. Walker, Executive Engineer, (Meerut,) by post, on Paper No. Q.

In the future this question may be an important one in the United Provinces where we already have 90 miles of cement concrete roads and where additional miles are being steadily added. These miles are standing very well and the question is not an immediate one.

The success of the thin concrete slabs which are only 2 or 3 inches thick is believed to be largely due to the excellent foundation on which they are laid. In England and elsewhere a very usual form of road construction is to provide a cement concrete foundation and over this to lay a black top travelling surface. If our concrete becomes worn or cracks badly it can then be used as a foundation for a bituminous grouted surface or a premix or even a thin bituminous concrete sheet. I personally see no reason why another thin cement concrete slab should not be laid over the old concrete thus giving another 15 to 20 years life to the road.

2. Comments made by Mr. H. M. Surati, (Hyderabad-Deccan), by post, on Paper No. Q.

Our thanks are due to the Author for stimulating the solution of problems that engineers will have to face, in the not distant future, in the restoration of cement concrete roads.

When the cement concrete roads were first introduced in the City of Hyderabad some nine years back there were some criticism and discussion among the local engineers about their future restoration and the general trend was in favour of some sort of coat with tar or asphalt concrete as suggested by the Author.

To my mind, the question will have to be decided on the condition of the road at the time the restoration is taken up and on the nature and intensity of traffic it has to carry.

Take a case when the engineers are wide awake and are able to bring home to the authorities concerned the necessity of restoring a cement concrete road which has begun to show signs of potential failure by the

appearance of numerous cracks here and there which were not there all these years; or the road has not cracked but there is rapid wearing due the top rich coat having worn out exposing the lower weaker coarse in case of two course construction. Then even a coat or two of bituminous paint with appropriate size of sand or chips depending upon the roughness of the road, would serve the purpose and be economical if there is not intense iron tyred cart traffic. These coats may have to be renewed every two to four years depending on the intensity of traffic and particularly of the iron-tyred type.

But the engineers may misjudge or the authorities may fail to realise the necessity of restoration by absence of any discomfort in the riding qualities of the surface; then the road would continue to serve its useful purpose for another four or more years before the necessity of restoration is born upon the authorities. This one would expect in the present state of our finances. The road would have broken up in smaller blocks, with unequal settlement or wearing with wide ugly and uncomfortable cracks. The author also envisages such conditions when he recommends in the last but one para on page 2 (q) *viz.*, "all broken up and loose parts of the concrete must be removed carefully and the whole surface plastered dead smooth". It is here and also on roads with intense iron-tyred traffic that the treatment will have to be different. It is submitted that an additional thickness of cement concrete would be best, for, the tar and asphalt concrete for Indian climate and traffic are plastic and become more plastic during summer and would bring up the defects of the old cement concrete road, as they are not capable of overcoming or of bridging the defects of foundation, which an elastic hard material like cement concrete is capable of.

What thickness and specifications should be adopted can best be determined by experiments or experience. Thicknesses varying from 2 inches to 4 inches depending upon the condition of the old road and intensity and nature of traffic, may be tried, bias being always for greater thickness. For, it is false economy to put smaller thickness, as it is believed that when the top $\frac{1}{2}$ inch to 1 inch thickness is worn the remaining small thickness of $1\frac{1}{2}$ inches to 1 inch in case of 2 inches slab may not be able to stand the pounding and hammering action of traffic and may reproduce the defects and cracks of the old road. It is not necessary to aim at uniform thickness of the new coat as in the case of plastic materials like tar and asphalt; on the contrary, it is believed that the uneven surface, and hence varying thickness, will afford better hold and more effectively resist the temperature stresses and warping of the slab, than a uniformly thick slab.

As to the precautions in and specification of preparing the surface and laying and proportioning of the renewal coat, it would be a paper in itself.

Finally I may draw attention to the second para of page 3 (q) of the paper under review wherein it appears that the Chief Engineer of City of Pittsburg is not quite satisfied with the behaviour of this thin road paving which moves under traffic. I wonder as to whether it would not be better in this particular case to fix an additional iron plate over the aluminem plate with suitable surface pattern or grooves filled flush with suitable cement or bituminous concrete or even without any filling with a different pattern of grooves with some sort of cushion sand-wiched in between the two plates, if necessary. In the latter case, there may be the nuisance of rattling under iron-tyred traffic but I presume that kind of traffic is negligible in that world. Will the Author kindly enlighten me on this point?

3. Reply by Mr. W. A. Radice (Author) to the comments on Paper No. Q, received by post.

To begin with, I desire to thank the Secretary to the Congress for forwarding to me, here in England, the comments made by members when my Paper was read at the meeting held in Calcutta. I am also very grateful to Mr. E. S. Kirk for so kindly presenting the Paper for me and to the numerous members who were good enough to express opinions on the subject I have brought to the attention of the Congress.

As regards the discussion itself, that part of it which partakes of the nature of criticism has been already dealt with, initially by Mr. E. S. Kirk in introducing the paper and finally by Mr. G. P. Bhandarkar, the Chairman, in summing up the discussion, both pointing out that my Paper limited itself to the *impersonal* presentation to the Congress of certain facts which had come to my notice and which, I considered, might be of general interest to the Congress and might even cause tests or research to be undertaken in good time.

The next point which emerges from the discussion is the appositeness of the Paper itself as regards the time of its presentation. Mr. G. B. Vaswani thinks that as concrete roads are expected to last 25 to 30 years there is plenty of time to enable *concrete experts* to discover a method of producing an everlasting surfacing process. Against this opinion Rai Bahadur A. C. Mukerjee, of the United Provinces stated specifically that the problem has been engaging the attention of the road engineers of his province for some time. Where fact is opposed to speculation, it seems wise to be guided by the former and to ignore the latter. This point of view is supported by Mr. D. Nilsson and I feel that many members must have considered his recommendation that tests should be undertaken immediately, most valuable and opportune. Tests can easily and cheaply be carried out and perhaps, the Technical Committee of the Congress, may consider it worth their while to encourage such action by individual members who are in a position to carry them out and to coordinate these individual efforts on homologous and comparative lines.

Mr. G. B. Vaswani in drawing the attention of members to the slight defects of the original specifications discovered in practice by the Chief Engineer of the City of Pittsburg and to his recommendations for improving the mix in future replacements has performed a valuable service to those who may be planning tests. I think, however, that this critic cannot be acquitted of a certain tendency to superficial thinking. He has omitted from his quotations from the Chief Engineer's letter the sentence

"In general, however, the paving has been very satisfactory and there has been no difficulty with adhesion between metal plates and the asphalt surfacing."

Nobody will deny that specifications of asphalt pavement can be varied within very wide limits and no doubt, any member carrying out tests, will avail himself fully of this latitude. What seems to me the most important and valuable result, resulting from the Pittsburg pavement described, is that it provides positive and definite information as to *adhesion* between asphalt pavement and a smooth aluminium surface. This being so, it would seem as

indisputable that an asphalt pavement laid on a worn-out concrete surface should not fail owing to insufficient adhesion between the two materials. This is a consideration of the highest importance, especially as none of the members who expressed a preference for a concrete resurfacing made any reference at all to any experience they may have had as regards this governing factor.

With these considerations in mind, the silence of the asphalt and tar expert members, usually strongly represented at Congress meetings induces in me the speculation that the Pittsburg experiment may have, in their opinion, strengthened the case of the concrete road supporters. Throughout my career I have always deplored the division of the steel and concrete interests as regards bridge construction and have been strongly convinced that a fusion of these antagonisms to ensure the proper use in the proper place of the proper material would be to the advantage of the community as a whole. The case in point would appear to offer a similar opportunity for fusion between the asphalt and tar and the concrete road supporters.

Turning to another aspect of Mr. G.B. Vaswani's remarks, I would like to remind him that my paper *recommended* nothing, except perhaps the carrying out of tests.

Mr. Brijmohan Lal's opening statement seems to me unduly pessimistic of Indian working conditions. In many fields of the art of Engineering, Indian Engineers have lead the world, not only in scientific analysis and in theory but also in practice; especially in river training and irrigation. I would deprecate the type of remark that might lead a foreign reader to conclude that Indian Engineers suffer from an inferiority complex. The land abounds with magnificent engineering works to disprove it.

I think I can reply to Mr. Dildar Hosain's first two queries. His first query is obviously due to lack of clearness in my paper and I wish to express regret for it. In Pittsburg the thin asphalt paving was put on to aluminium plates forming the deck of a bridge. On roads, the asphalt pavement would be laid on the worn-out concrete surface; no aluminium would be used.

As regards his second query, the floor system of the Smithfield Street Bridge consisted of a flat aluminium deck plate $\frac{3}{8}$ inch thick supported by longitudinal aluminium channels 8 inches deep, placed on edge at 8 inches intervals and resting on the cross girders of the bridge. The total weight of the floor system and surfacing including the asphalt paving, aluminium deck plate and channel stringers was about 34 pounds per square foot; a very light flooring indeed.

I must bow to Rai Bahadur A. C. Mukerjee's experience with thin concrete slabs. I would enquire whether these slabs were actually used on worn-out concrete roads, and if so whether the bond between the old and new material has effectively withstood the test of time. This seems to me the crux of the question, that of bond or adhesion and on this point we cannot have too much evidence.

The opinion expressed by Mr. S. G. Stubbs that a thin bituminous carpet laid on concrete, will fail due to the aggregate getting crushed, is so entirely contrary to the Pittsburg experience that I consider it should not

discourage investigators until one or the other divergency is established by tests in India. Mr. H. B. Parikh's experience on the Lloyd Barrage supports Mr. Stubbs' opinion. It would be interesting to compare the specification of the Lloyd Barrage road carpet with that used at Pittsburg in an effort to account for the reported divergency of results.

Mr. W. F. Walker refers to the use of a black top travelling surface over a cement concrete foundation very usually used in England and elsewhere. I shall try and obtain detailed specifications of this black travelling surface and particulars of its behaviour and if obtained shall be happy to communicate them to the Congress. His suggestion of another thin concrete slab omits any reference to bond and adhesion between the old and the new.

I have read with a very real interest Mr. H. M. Surati's comments. He brings up the very interesting point that funds for repair of worn out concrete roads might not be available at the optimum period, and that therefore methods of repair will vary according to the amount of deterioration which has accrued. There can be no doubt in the mind of anybody experienced in the methods of financing road repairs in India that the contingency envisaged by Mr. Surati is more than probable.

I do not pretend to be a road expert, as I clearly explained in my Paper and so will not venture to comment on Mr. Surati's highly practicable suggestions; there is more than ample talent among the members of the Congress to do so competently, and my hope is that some member or members may be induced by Mr. Surati's remark to submit papers analyzing the possibilities in greater detail. The question raised by me superficially enough is going to be so important in the near future that the value of discussion and experiment at the present time, before a wide-spread need of action has arisen, can hardly be exaggerated.

As regards Mr. Surati's concluding question, I can say that iron-tyred traffic is unknown in American cities and would not be tolerated for one moment. The public demands good roads, easy to ride over and whilst it is content to leave the economics of road repairs to the experts paid to carry them out, it refuses to submit to the general discomfort of having to travel over roads damaged by a type of vehicle wheel which can be eliminated by the stroke of the pen.

Summing up the discussion; there seems to me that the following points have been made,

1. That the subject is of growing importance.

2. That experimental work is necessary, and it would appear to me that the sooner experiments are made on the best means of correcting various degrees of disrepair of concrete roads the more efficiently will the money available be used when the time comes.

The discussion has also suggested to me a profitable line of enquiry which perhaps the Technical Committee will take up, in view of its para-

mount importance. That is the question of the economics of Road repairs. There should be an optimum moment and optimum methods for repairing every type of road surface in order to keep the cost of maintenance of fixed standard of surface excellence. Perhaps it is impossible to discover any fundamental guiding principles in such a complex question, I do not know. I merely throw out the suggestion in order to stimulate thought amongst the members. I feel sure that if the Congress offered a prize for contributions by the road engineers of India of their ideas and experience on such a subject, it may be possible to collect material from which some guiding principle or principles may emerge.

All that has been said in this discussion, and especially what has been omitted, confirms in my mind that the question of load is the real crux of the problem and I would invite experimenters to devote special attention to this factor.

PAPER No. I

Mr. P. V. Chance (Chairman) :—I will ask Mr. Nilsson to introduce his Paper No. I, on "Submersible Bridges."

The following paper was then taken as read :—

PAPER No. I.

SOME NOTES ON SUBMERSIBLE BRIDGES

By

D. NILSSON, B.Sc., M.I. Struct. E.

Submersible bridges, bridges that can be submerged and still remain undamaged, are fairly well-known in India but not in Europe. They are not uncommon in Australia and Africa also. As most text books come from Europe or America there are not many that deal with submersible bridges and personally the author does not know of any. A few remarks on this subject may therefore be of service to those who have not already had experience of this type of structure.

The chart marked Figure 1 gives the heights of floods (vertical axis) and dates (horizontal axis) in the River Wainganga at the site of Bhandara Bridge during the monsoons of 1928 and 1929. This chart is a typical example of what is obtained on many rivers in India. Very high floods occur three or four times during the monsoon, but the water level rises so fast and falls again so rapidly that the peak levels of these floods only last for a very short time, usually a matter of a few hours, and the bridge is only out of use for a short period.

During the monsoons shown on the chart the floods did not reach the maximum high flood level which is about R.L. 110. A high level bridge to cover this would require to have its road level at about R.L. 118, but it was built as a submersible bridge with road level at R.L. 104.75 as shown in Figure 5. If the bridge had been built as a high level bridge with road level R.L. 118 it could be seen that it would not only have been much higher than the submersible bridge but would have required to be longer in order to pass the flood waters without seriously affecting the afflux level. Probably the high level bridge would have required to be about eighteen bowstrings or similar type spans of 100 feet each and would have cost much more than the submersible bridge. During maximum high floods much of the country all around is under water and long approach embankments would have been required at either end of a high level bridge.

The point to decide considering the traffic to be carried is whether the few hours that the submersible bridge is liable to be closed are worth the extra cost of building a high level bridge.

Now even though the flood chart may indicate that a submersible bridge would be adequate the site may be such that a submersible bridge would not be suitable, or it might cost just as much or even more than a high level bridge. No two sites are ever exactly the same and therefore hard and fast rules cannot be laid down. I think the simplest and clearest method of

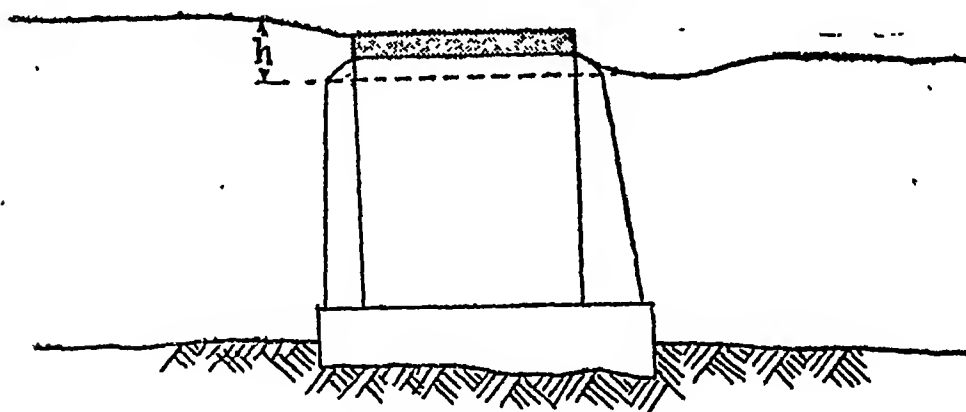
2 (i)

illustrating various points will be to give examples and discuss the points in each example. But before doing this the conditions which a submersible bridge must withstand might be mentioned.

A submersible bridge has of course to carry the same live loads as any other bridge as well as its dead load. But in addition, it has to withstand a very considerable horizontal thrust and perhaps an upward lift from the flood waters. Further when the flood is passing through the openings of the bridge the velocity of flow is materially increased and more than usual scour must be anticipated.

The worst flood effects will probably occur when the water is just overtopping the bridge. I do not think that an accurate estimate can ever be made of the forces acting upon the bridge under this condition. It is, therefore, considered sufficient to make rough approximations of these forces, being careful that the results are not less than what may possibly occur. The following simple method has been used for many years with satisfactory results.

When a flood tops the bridge the level of the water at the top of the forward edge of the upstream coping will be banked up as shown exaggerated in the sketch below. At the down stream side of the bridge there may be the trough of a standing wave if the velocity of flow is high.



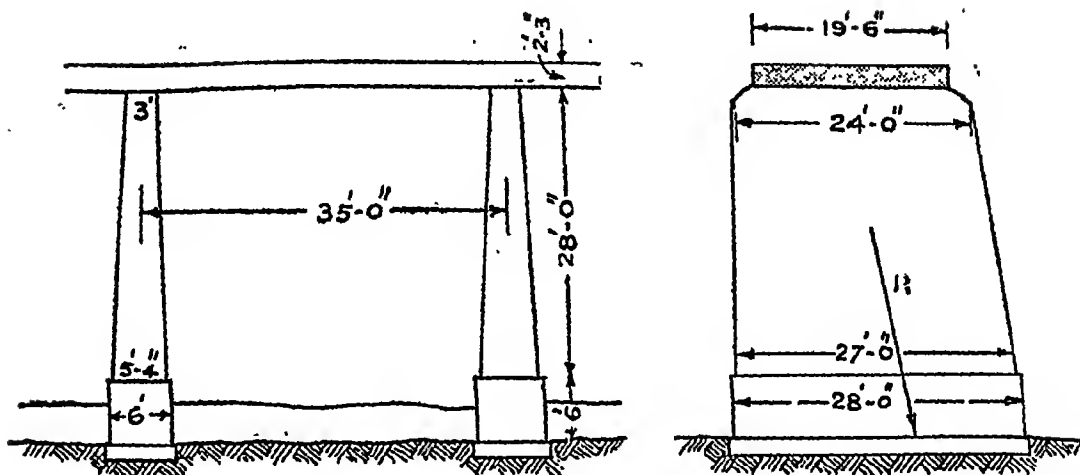
The forces can therefore be broken up into :—

- (i) That due to the static head 'h'.
- (ii) That due to the impact of the water and debris.
- (iii) That due to eddy motion at the back of the piers.
- (iv) That due to the friction of the water against the piers and soffit.
- (v) Uplift due to the head equal approximately to the thickness of the superstructure plus the afflux

In addition it must not be forgotten that the dead load of the structure is reduced by 62.4 pounds per cubic foot when submerged.

3 (i)

Take as an example the bridge sketched below :—



Then working out each of the forces mentioned above :—

(i) The pressure due to the static head will be 'h' times the weight of water per cubic foot 'w'. This pressure will act over the whole horizontally projected area of the bridge obstructing the flow. In estimating this area the maximum scour must be assumed to have occurred. Assuming that the deck of a bridge is 27 inches deep and that the obstruction to the flow raises the surface level 9 inches in front of the upstream edge of the coping and that the water emerges 1 foot below the soffit at the downstream edge, the pressure then will be

$$\begin{aligned} wh &= 62.4 \text{ (9 inches + 2 feet - 3 inches + 1 foot)} \\ &= 250 \text{ pounds per square foot.} \end{aligned}$$

It is not quite correct to say that this pressure will act over the whole horizontal projected area of the bridge as the pressure within the height 'h' will vary from 0 to 'wh'. However it is doubtful whether the saving made is worth the trouble of working out the two separate areas, pressures, and centres of pressures.

Molesworth's Pocket Book gives the following formula for calculating the rise of water caused by an obstruction,

$$R = \left(\frac{V^2}{58.6} + 0.05 \right) \left\{ \left(\frac{A}{A-a} \right)^2 - 1 \right\}$$

where V = velocity of river previous to obstruction in feet per second.

A = Sectional area of river unobstructed in feet.

a = area of the obstruction.

In the example taken this would give $R = 0.81$ foot.

This formula depends upon the constants included and they must vary for each river bed and it is probable that some reasonably safe assumed figure would be just as good.

4 (i)

(ii) For estimating the pressure due to the velocity take the area of flow of the river just upstream of the bridge as 'A' and the area of the obstruction as 'a'. Then the pressure due to the velocity is:—

$$\frac{wv^2}{2g} \left(\frac{a}{A-a} \right)^2$$

where v = velocity of approach

In the example A = 1295 square feet. a = 231 square feet assume v = 10 feet and then the pressure becomes:—

$$\frac{62.4 \times 10^2}{2 \times 32.2} \left(\frac{231}{1064} \right)^2 = 4.6 \text{ pounds per square foot.}$$

(iii) The loss in head due to the sudden enlargement of the stream after passing the bridge i.e., the loss of head due to the formation of eddies will be:—

$$\frac{('v' \text{ through bridge} - 'v' \text{ after passing bridge})^2}{2g}$$

Assume the velocity through the bridge to be 15 feet per second and after passing the bridge 10 feet per second then the pressure due to eddy motion is:—

$$62.4 \frac{(15-10)^2}{2g} = 24.2 \text{ pounds per square foot.}$$

The velocity through the bridge has been assumed but if the velocity above the bridge is 10 feet per second it is easily calculated that for the obstructed area of flow it should be 12.2 feet per second. However as it is impossible to know the contraction which may occur or the other possible obstructions, such as the bed not being scoured to the supposed level, it is advisable to assume a velocity which is on the safe side.

(iv) The friction on the bridge can be represented by a formula:

$$F = f.p. \left(\frac{v}{10} \right)^2$$

where 'f' is the friction co-efficient between the water and the bridge when the velocity is 'v' and 'p' is the area of the surface of the bridge in contact with the water.

The co-efficient 'f' was given by Froude in experiments made many years ago as 0.588 pound per square foot for coarse sand. The author has not been able to find any more suitable experimental results. The coarse sand figure would it is thought be low for masonry such as is generally used in bridge piers and a safer figure would be 1 pound per square foot. Then in the example we have:—

$$F = 1 \times 2388 \times \left(\frac{15}{10} \right)^2 = 5,400 \text{ pounds.}$$

This is equivalent to a pressure of about $23\frac{1}{2}$ pounds per square foot on the area of obstruction.

The formulæ given under (ii) and (iii) are derived from the flow in pipes and it is likely that they are not correct for open channels, but it is

5 (i)

considered that they are sufficiently accurate for their purpose which is to give a safe idea of the lateral pressure on a bridge and not to delve deeply into hydraulics. It is possible to combine the results of (ii), (iii) and (iv) by using Gibson's formula derived from dragging a solid through water ; it is

$$P = C \frac{wv^2}{g}$$

Here again we have a constant 'C' which must be filled in according to the type of obstruction offered *e.g.*, flat ends, one flat end, one tapered end, both ends tapered etc., and it may vary from 0.55 to 0.125.

(v) The uplift head under the slab may be the thickness of the slab, plus the assumed afflux, less the head lost due to increase in velocity. In this case to be again on the safe side take the minimum velocity under the bridge as 12.2 feet per second. The uplift pressure then becomes:—

$$62.4 \left\{ 2 \text{ feet}-3 \text{ inches} + 9 \text{ inches} - \left(\frac{12.2^2 - 10^2}{2 \times 32.2} \right) \right\} = 140 \text{ pounds per square foot}$$

Of the horizontal forces it is seen that (1) is very much the greatest. In arriving at this force the afflux and the fall below the bridge must be known and at present can only be estimated approximately or guessed. It would be of great service if those engineers who have submersible bridges under their charge could observe and report to the Indian Roads Congress on the variations in these levels and the velocity of the river above and through the bridge. Even roughly measured figures would be of assistance.

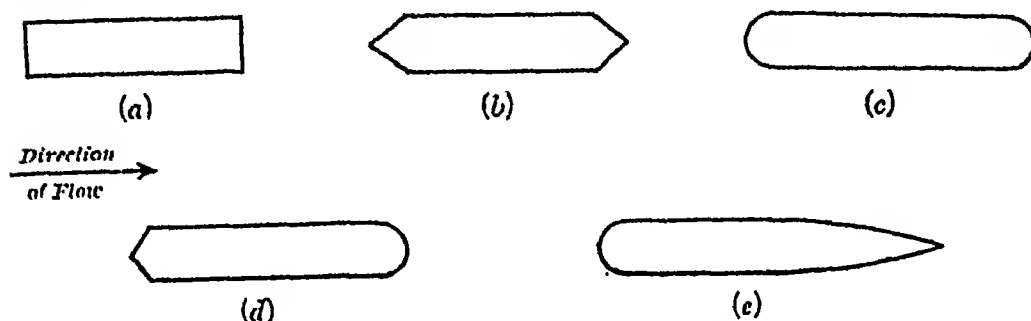
All the horizontal forces may be greatly increased if as frequently occurs large quantities of timber are carried down during floods. Where this may be expected the engineer must estimate how much further obstruction may be caused by trees sticking against piers and under the deck. Small low spans are much more liable to become blocked with debris than larger spans having ample clearance between the ground and the deck soffit. Photograph III shows whole trees held up against the Mandla Bridge.

The stability of the bridge under these horizontal forces must be checked and when doing this the dead weight of the piers must be reduced by 62.4 pounds per cubic foot. This gives a resultant force acting as 'R' on the sketch, and as this falls within the middle third of the pier the structure is safe. If necessary the pressures on the masonry and the foundation at the downstream end of the pier may be checked, and as long as these pressures are safe the pier will be stable whether the Resultant falls within the middle third or not. However, it should be noted that in order to contain the Resultant within the middle third the downstream end of the pier has generally to be given a greater batter than the upstream end.

If the piers had been founded on piles instead of on rock the problem would not be so simple. Allowance would have to be made for bending in the piles or for raking piles to take the thrust. The piles would also have to be arranged so as to accommodate the extra load which would come on the downstream piles.

As regards the shape of the piers it is common to find both ends the same, square (a), pointed (b), or rounded (c). Another common arrangement

is to have the pier pointed at the upstream end and rounded at the downstream end (d). This rounded downstream end is certainly better able to take the increased pressures which occur there. However these pressures are generally small enough to be neglected and it would be better to shape the pier to cause as little eddy motion as possible. The eddy motion forces on the bridge are admittedly very small but they are an important cause of scour.



The piers would therefore be best shaped as at (e) with the upstream end rounded and the downstream end tapered as slowly as reasonably possible. This may sound rather revolutionary but one has only to consider the shape of the cross section of an aeroplane wing to realise that it is the nearest to correct streamlining. Or it may be justified from the formulae already given :—

(i) & (ii) The horizontal projection of the bridge is the same whatever the shape of the front of the pier and therefore these two forces remain the same.

(iii) The velocity of the water will be gradually reduced owing to the gradual widening of the distance between the pier faces with the tapered downstream ends. That is at two adjacent sections

$$w \cdot \frac{(V_1 - V_2)^2}{2g}$$

will be very small.

To avoid excessive obstruction to the flow of the river when the bridge is submerged there must be either no railing or else some sort of collapsible or removable railing. Figure 2 shows a type of collapsible railing which was designed by the Central Provinces Public Works Department and has proved successful on many bridges.

The bridge over the Narbadda River on the Bombay-Agra Road though very high above the river bed has a railing only on the upstream side. This railing falls horizontally by the force of the flow when the flood tops the bridge. Some engineers specify wheel guards, others posts with removable chains hanging between them, and in some cases where the bridges are low there is no side protection at all.

The following are some examples of submersible bridges :—

Wagholi Bridge.—Figure 3 and Photograph I was one of the first reinforced concrete submersible bridges to be built, being completed in 1927. Very flat arches having a rise span ratio of 1 to 10 were used in order to cause the

minimum obstruction during high floods. These flat arches also have the effect of passing ordinary floods without the obstruction which would have been caused by the springings of arches of ordinary dimensions. The river carries down much debris and this bridge was therefore designed with perfectly flat spandrel walls and no cornices or projections which could become damaged by floating logs or trees.

The bridge was founded on reinforced cement concrete piles. No raking piles were employed under the piers as the pile caps were taken down into the clay to a depth below which scour was not anticipated.

At the site of the bridge the left bank is very high and steep so that the approach is in cutting. On the other bank the general ground is level with the bridge road surface and there is therefore no embanked approach. This is an important point concerning submersible bridges; avoid approaches on embankments and if possible have the approaches in cutting or at ground level. Where the current is at all swift embankments are very difficult to protect adequately and may form a continual source of trouble and expense. In cuttings the flood will only form a back water and some silting may occur, but with adequate side drains the road will not be damaged.

Mandla Bridge.—Figure 4 and Photographs II and III. This was an old bridge built by the Public Works Department over the Narbadda River in 1913. It consisted of eighty 20-foot arches built of brick or of lime concrete stone faced, with lime concrete spandrels and stone paving. It gave satisfactory service until the monsoon of 1926 when several spans were washed away and much damage was done. The author's firm replaced the three central spans by a single reinforced cement concrete arch and the damaged causeway at the end by three reinforced cement-concrete arches and replaced the lime concrete spandrels by plum cement concrete in the remaining old arches. During floods this river brings down a great deal of debris including whole large trees. Photograph III shows a flood nearing road level. The tree which seems to be standing vertically as well as the other brushwood has been brought down by the flood and is stuck against the bridge partially blocking the waterway and hammering against the structure. When a river brings down much of such heavy debris the spans should be designed large enough and high enough to pass the trees etc., without their jamming. Of course in some rivers debris is not brought down until the flood has reached a considerable height and then the road level may be arranged so that all floating material passes over it.

Bhandara Bridge.—Figure 5 and Photograph IV. This is a very large submersible bridge being 1650 feet long and consisting of eighteen arches of 86 feet centres. The arches are of normal rise to span ratio and the type of superstructure is clear from the drawing.

The chief problem with this bridge was the foundations as the river bed consisted of waterlogged fine sand in some places as much as 35 feet deep. The sand lay over rock which was stratified, the layers being more or less vertical. Concrete cylinders were sunk as far as they would go by open dredging and then piles were driven inside and the cylinders afterwards plugged with concrete. It was found that the piles with a Gammon Patent cast iron shoe could be driven as much as 4 feet into the rock without damaging them. Though it could be expected that some scour would occur right down to rock this arrangement allowed of the piles being braced just above rock level.

so that there could be no bending moment in them. As an additional precaution boulder filling was placed round the pier bases and left to sink to rock level as scour occurred.

The approaches of this bridge were in shallow cutting or at ground level.

The author understands that this bridge has been submerged yearly since 1929.

Andura Bridge.—Figure 6. This bridge crosses the Purna River and although the road surface is about 40 feet above the bed level it is liable to be submerged by 15 feet of water. This is again an arch bridge which being very solid and heavy is eminently suited to withstand the large overturning moments that are produced by the horizontal forces on such a high bridge. The batter of $2\frac{1}{2}$ inches per foot on the downstream ends of the piers should be noted.

In the design of the arches the crown thickness and the cover at the crown are kept as small as possible in order to give the minimum obstruction to flow. The end abutments should be stable without the assistance of the pressure from the earth behind them which might possibly get washed out at any time.

The *Tapti Bridge* shown on photograph V is very similar to the Andura Bridge and a drawing of it is therefore not shown. As can be seen from the photograph the bridge is a large one but none the less in 1931 it was overtopped by 33 feet of water.

Bara Rewa Bridge.—Figure 7, Photograph VI. This is a beam and slab design deck suited to a submersible bridge. The road level being only about 15 feet above bed level, arches would have obstructed too great a proportion of the flow unless very small spans were used and that was impracticable on account of the rather expensive foundations. The bottoms of the beams are joined by a slab so as to give a smooth soffit.

Madhav Khadi Bridge.—At this small bridge of twenty spans of 18 feet each rock was showing at bed level so that small slab spans supported on reinforced cement concrete piers were economical. These offered so little obstruction that the piers could be made shorter than the width of the deck and still remain amply strong.

Kalpni Bridge.—Photograph VII. Being very low and offering but little obstruction it has been possible in this bridge to make some saving by reducing the length of the pile caps and having the piers narrower at the base than the top. The solid reinforced cement concrete slabs have their edges rounded to be less liable to damage. The road is protected by wooden posts sitting in holes in the deck so that they can be removed if desired or if not removed before submersion any which may be lost or broken can be easily replaced.

Sone Bridge.—Photograph VIII. A small submersible bridge combining a 75 foot arch and slab spans of 17 feet 6 inches. The arch spans the centre of the river where there is a considerable depth of water and waterlogged sand overlaying the rock and foundations would have been too expensive to continue the small spans for the full length of the bridge.

Kalisindh River Bridge.—Figure 8. This bridge has twentyfive spans each of 33 feet 8 inches. Four or five spans are designed and built as continuous with the result that a slab of minimum thickness is required

To further reduce the bending moment and hence the slab depths, the bottom of the slab is corrugated near the centre thus reducing the dead load there. These corrugations were formed by using steel troughing as centering.

Banas Bridge.—Photograph IX. This large bridge was designed as a submersible bridge, for although the high flood level is not expected to rise much above road level it is almost at road level. It was considered however that a fixed railing would be satisfactory. The bridge consists of eighteen arch spans each of 86 feet and ten slab spans similar to those in the Kalisindh Bridge. The small slab spans were used where rock level approached near the surface and enabled much cheaper foundations to be built.

Monaguni Bridge.—Figure 9. This is a small bridge which is at present under construction. It is an example of a submersible bridge on piles which are liable to be partially exposed due to scour. The piles pass through sand, gravel, and then clay overlying rock and it is possible that the sand may be scoured out. The piles on a batter will take up most of the thrust and be helped by the other piles which can withstand considerable bending moments.

The site is not ideal for a submersible bridge as there are approach embankments on either side. The road level was first proposed at R.L. 36.00. That would have avoided the embankment on the one side but would have meant that the bridge and the remaining embankment would be submerged yearly. By raising the road to R.L. 44.75 the increase in cost was very little and only very exceptional floods will submerge the bridge or embankments while all other floods pass under it encountering only little obstruction.

The author does not think that the costs of these submersible bridges will be of much service as their construction was spread over a number of years during which the cost of materials has varied considerably. Also foundations and sites always vary and affect the costs enormously. However in case the figures should be of interest a table of costs is given below:—

Name.	Year Completed.	Overall Length	Total Cost	Cost per running foot.	Cost per square foot of elevation area from bottom of foundations to top of coping.
			Rs.	Rs.	Rs.
Wagholi Bridge ...	1927	455'-0"	2,75,720	606	13-8-0
Bhandara Bridge ...	1929	1644'-0"	5,81,630	354	8-2-0
Andura Bridge ...	1931	490'-0"	2,86,499	585	9-8-0
Tapti Bridge ...	1931	590'-0"	2,82,965	479	12-12-0
Bara Bewa Bridge ...	1931	301'-9"	1,18,500	393	11-10-0
Madhav Khadi Bridge ...	1932	362'-6"	28,500	79	6-1-0
Kalpani Bridge ...	1932	101'-9"	39,000	383	5-7-0
Sone Bridge. ...	1933	195'-0"	24,500	126	13-10-0
Kalisindh Bridge ...	1934	952'-2"	1,71,602	180	9-4-0
Banas Bridge ...	1936	1987'-0"	4,30,385	217	5-2-0

Two points to which no reference has been made are the nature of the filling to spandrels and the road surfacing. It is obvious that the road surface must be of some material which cannot be washed away such as stone slabs or blocks set in cement or asphalt or concrete reinforced or plain. If

10 (i)

a reinforced concrete roadway has been provided it may be considered that the spandrels could be filled with earth or boulders but such a practice is liable to result in trouble. If the spandrel filling is pervious there will be a hydraulic upward pressure under the road surfacing due to the banking up of the river in front of the bridge. This upward pressure will considerably assist the water rushing over the bridge to break up the road surface and float it away. After this any weak filling would be quickly washed out.

Briefly the points to be watched in a submersible bridge can be summarised as follows :—

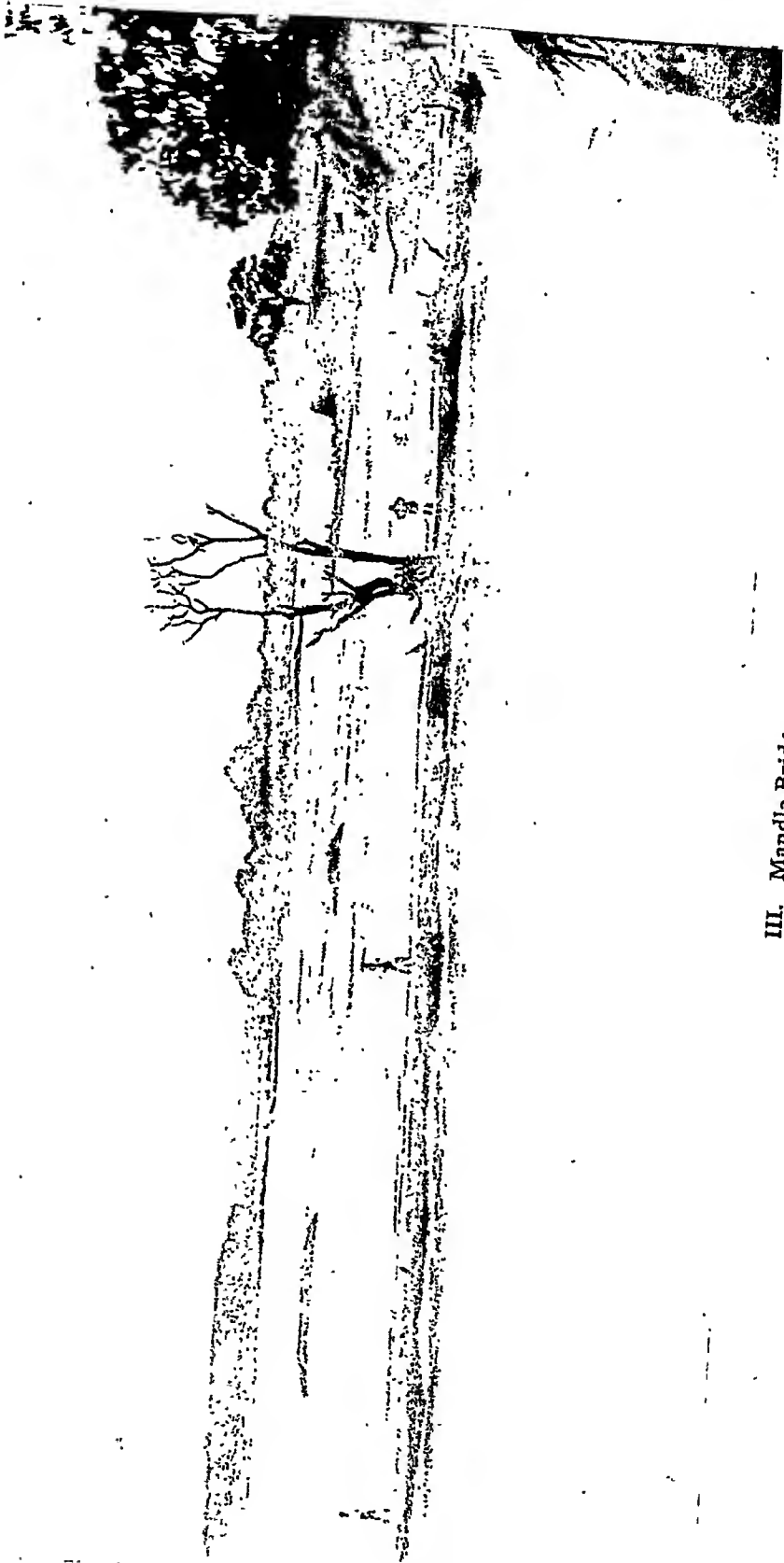
- (1) Choose a site where the approaches will not be in embankment.
 - (2) Make the spans long enough and high enough to pass all floating debris.
 - (3) Design the superstructure to be heavy enough not to be washed away and also to offer as little obstruction as possible to the flow of the river.
 - (4) Design the piers and foundations to be stable under the worst conditions of submersion.
 - (5) Use only impervious materials.
 - (6) Arrange for removable or collapsible railings.
 - (7) Avoid ornamentation or spaces in which debris can become entangled.
 - (8) See that the work carried out is of the best quality materials and workmanship.
-



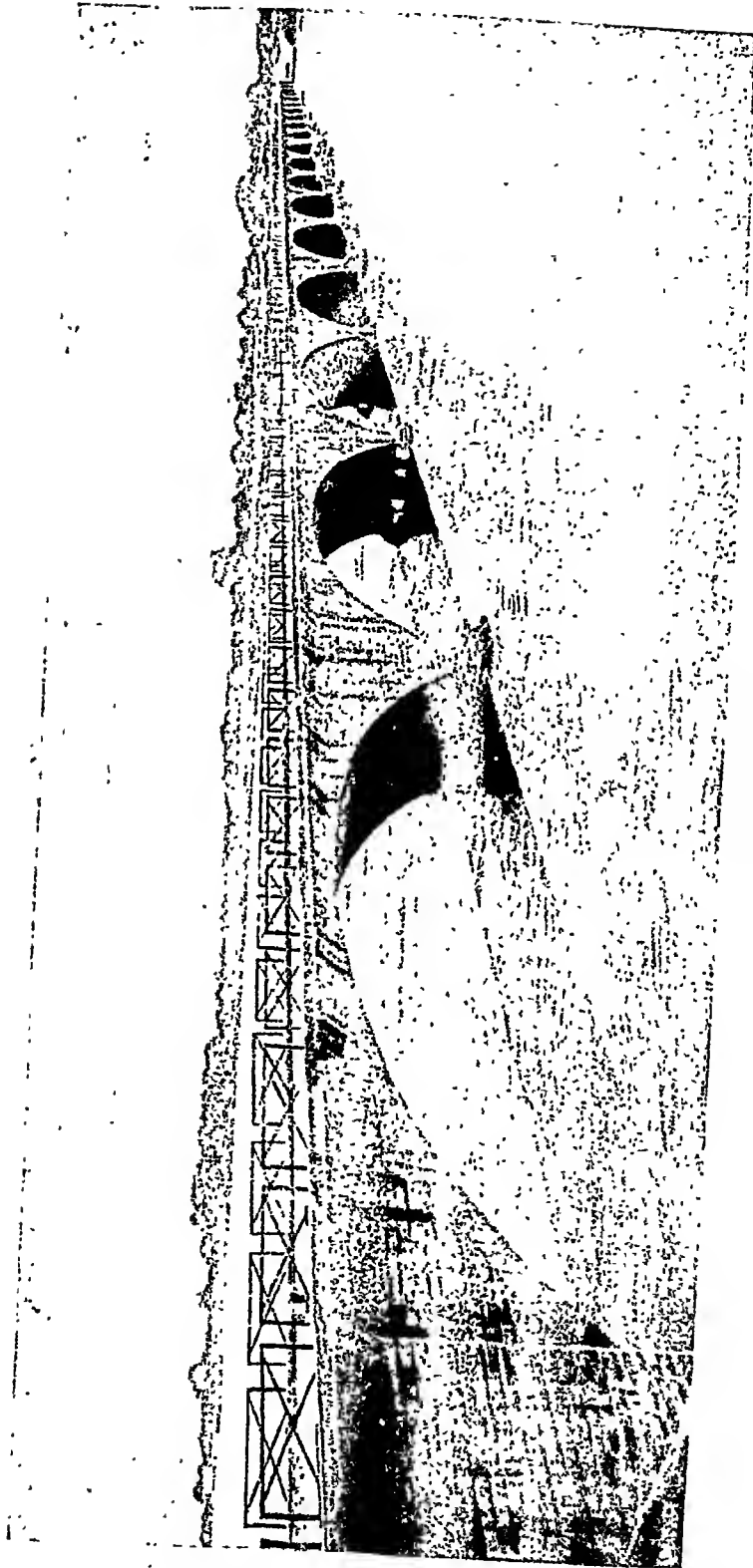
1. Wagholi Bridge.



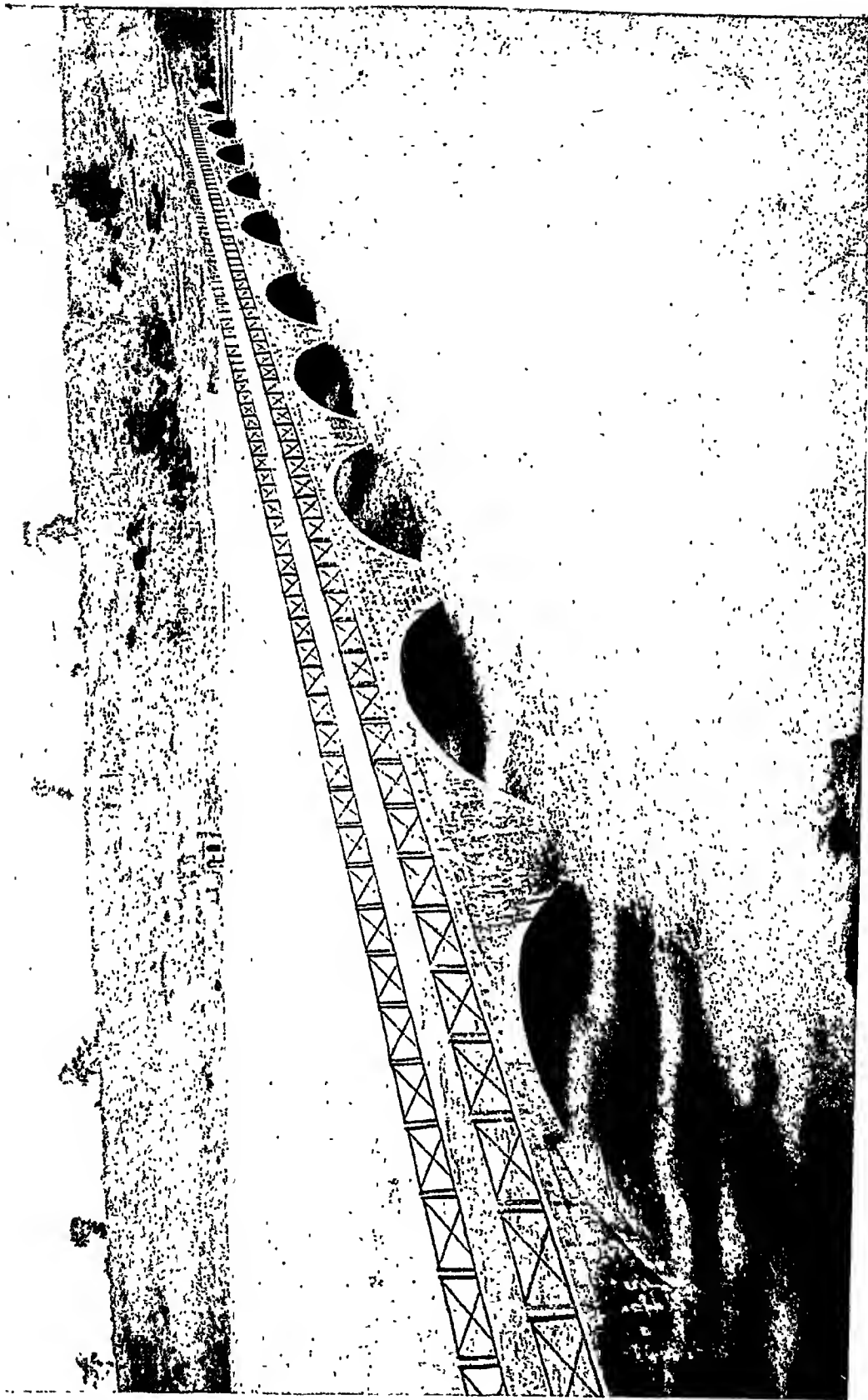
II. Mandla Bridge.



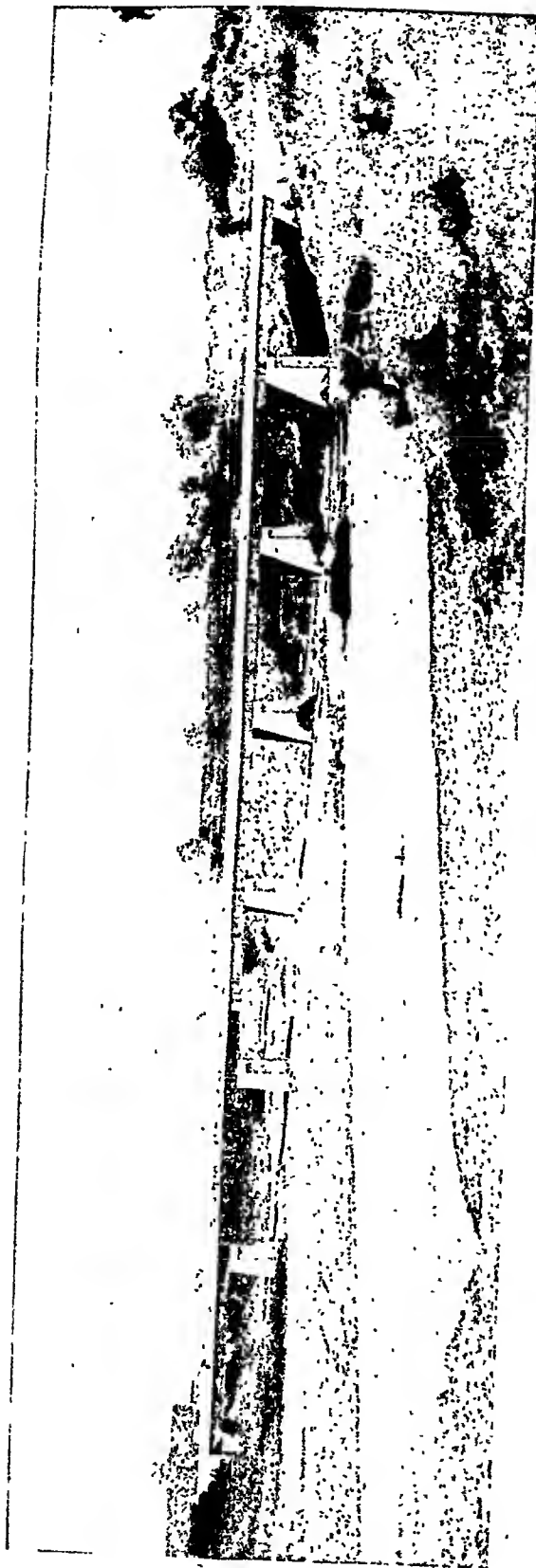
III. Mandla Bridge.



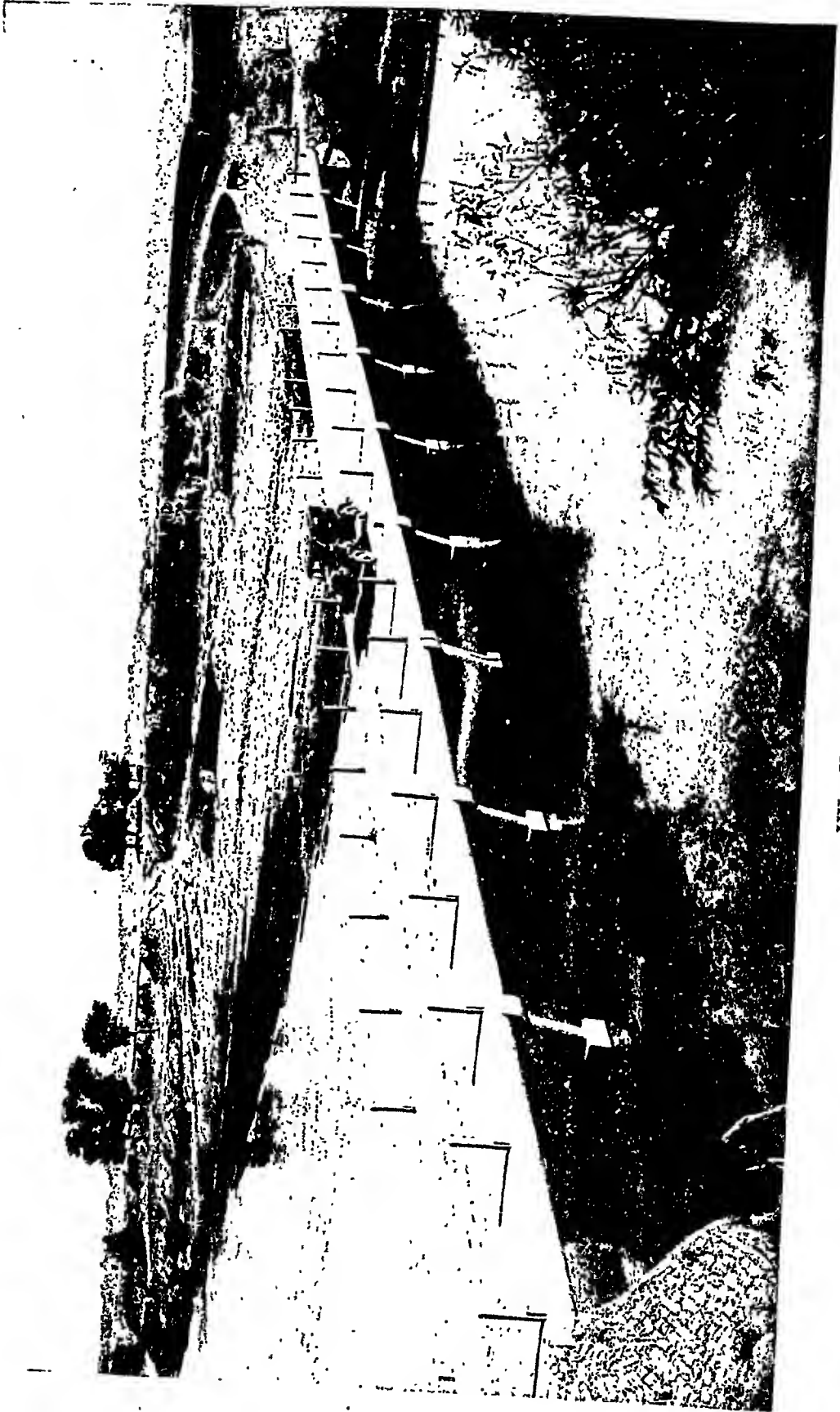
IV. Bhandara Bridge.



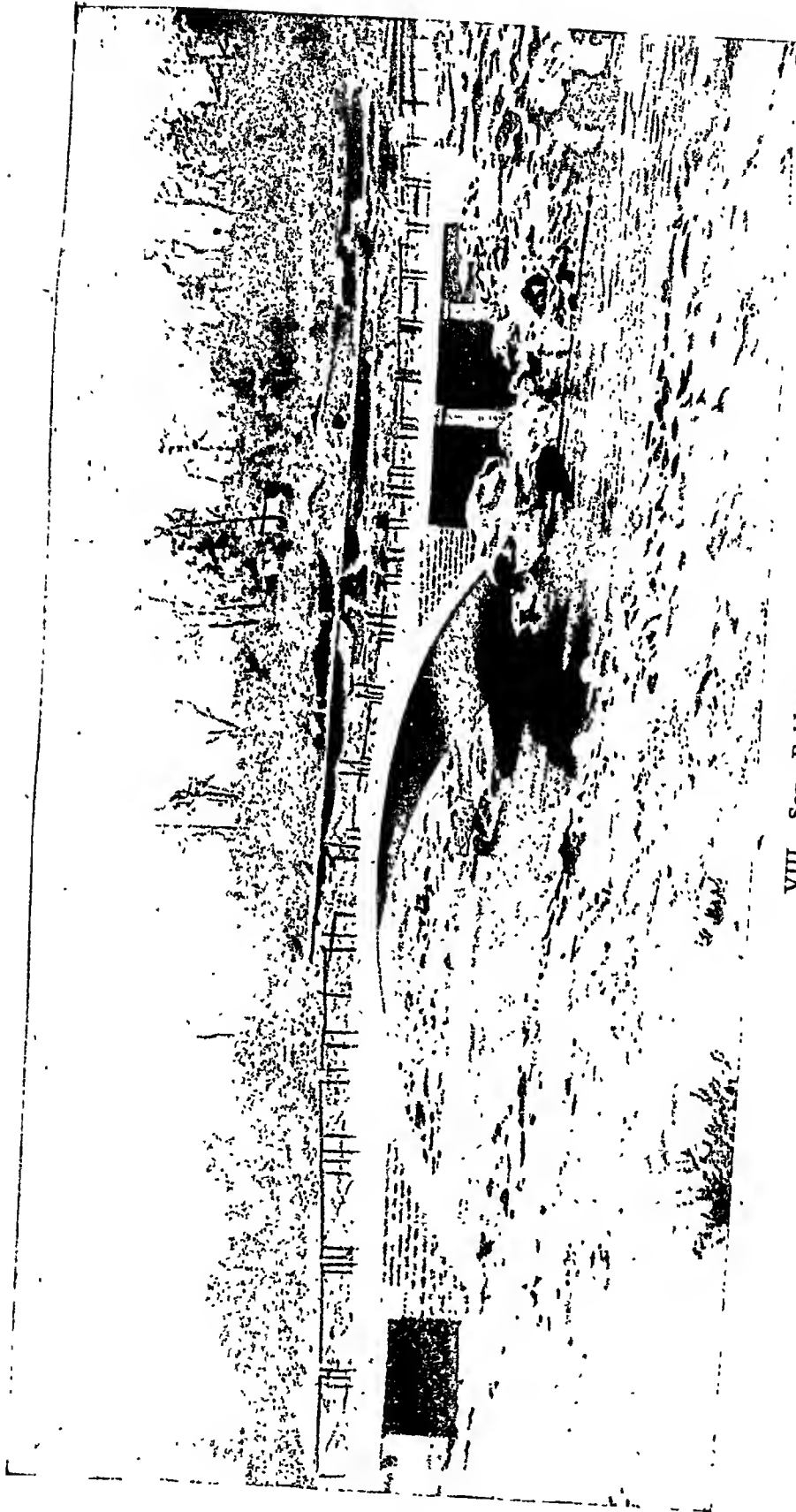
V. Tapti Bridge.



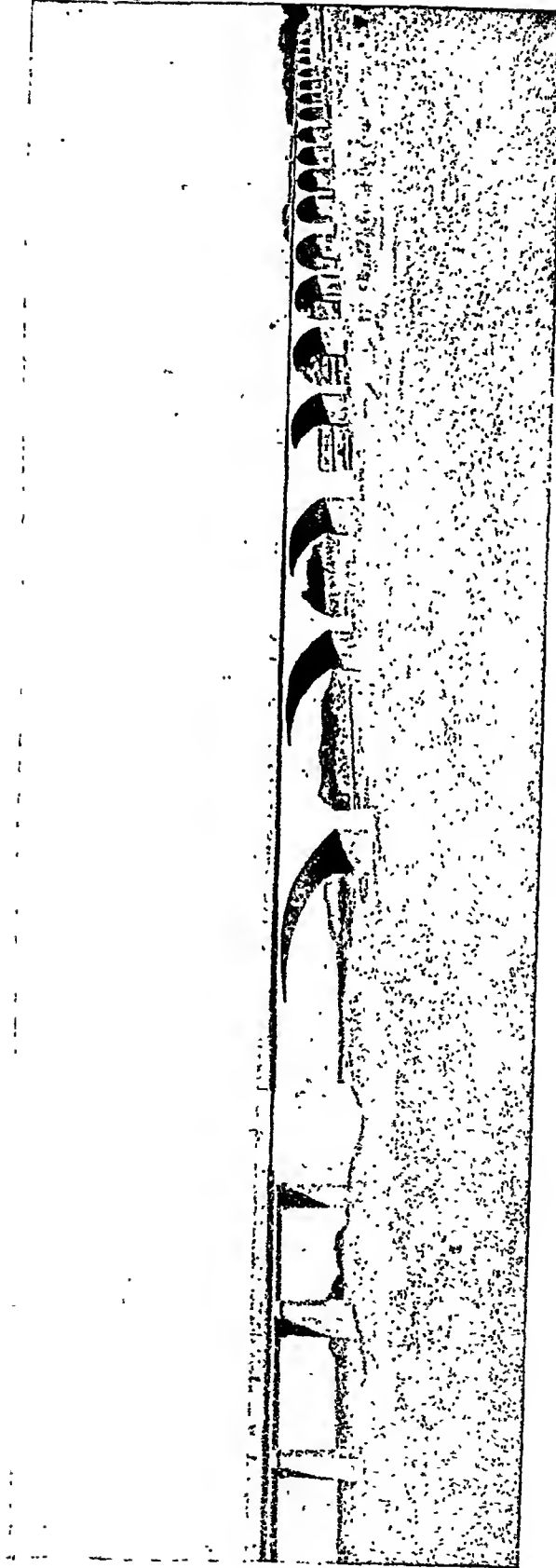
VI. Bara Rewa Bridge.



VII. Kalpani Bridge.



VIII. Sone Bridge.



IX. Banas Bridge.

DISCUSSIONS ON PAPER No. I.

Mr. D. Nilsson (Author):—Having read over this paper in the train coming across here, months after writing it, I think that I owe an apology to those people who are experienced in the construction of submersible bridges for having written such an elementary paper. However, if it produces the facts and figures which I am anxious to obtain, then I think it will have served some purpose. If any of you has got a submersible bridge in his charge, what I particularly want to know is, when a flood is just going to over-top the bridge, how much is that flood banked up, i.e., how much is the afflux? Also, when the flood emerges from the down-stream side of the bridge, what shape does it take and what level is the water compared to the level of the bridge deck? If accurate data on these points were available, I think that we might be able to obtain more correct figures than those produced by the rough formulæ which I have shown in my paper. I hope that those Engineers who have submersible bridges in their charge, will try to obtain such figures during the next monsoon and submit them to the Roads Congress.

Mr. McKelvie (Central P. W. D.):—1. It is unfortunate that the Author has taken the graph of the flood levels at the Wainganga bridge at Bhandara to illustrate typical flood variations of rivers over which submersible bridges are required. The Wainganga at Bhandara is relatively a slow flowing stream. Far more typical are the graphs of the Tapti at Burhanpur, the Purna at Wagholi and Andura and the Bara-Rewa near Narsingpur described in the paper. Other typical rivers in the Central Provinces are the Narbadda at Tilwaraghat and Jogi Tikaria, the Man at Balapur, the Kanhan at Rimakhona, the Penganga at Chikli, the Pench, the Johilla, the Chota Purna and a host of others.

As stated in the paper, the highest recorded flood over the Tapti bridge at Burhanpur was 33 feet higher than the bridge formation level and about 36 feet higher than the ordinary flood level. In the case of the Narbadda at Tilwaraghat, the highest recorded flood was 85 feet above summer water level, 53 feet above the average monsoon flood level and 48 feet above the bridge formation level.

The Bhandara bridge was, at the time of its design, regarded as a "border line" case and figures were taken out to see whether a submersible bridge or a high-level bridge would be more suitable. The other bridges mentioned above are not "border line" but typical cases necessitating the construction of submersible bridges. The Tilwaraghat submersible bridge, for example, cost with its approaches about Rs. 7/- lakhs while the railway high-level bridge constructed at the same time and a few miles down-stream cost Rs. 44/- lakhs.

The Author has not stressed the fact in his paper that a submersible bridge is constructed *only when it is cheaper than a high level bridge* and then too, cheaper to an extent sufficient to compensate for the fact that it will be out of action for a short period every year.

2. It may be of interest to members if some remarks are recorded on the history of a few of the bridges described in the paper. Some of these bridges are not to be regarded as examples of the last word in the design of structures of this type but rather as illustrating stages in the development of the technique of submersible bridge construction.

In a new art or science such as this, more can perhaps be learnt from a discussion of improvements in technique than from a mere description of actual structures which may not represent the latest accepted practice.

Briefly, the flat arches of the Wagholi bridge were afterwards regarded as a bad mistake. The Bhandara bridge was also designed with fairly flat arches but during construction the rise was increased by 6 feet. An analysis of rise-span ratios for solid spandrel submersible bridges in the Central Provinces some years ago showed that a rise of one fifth of the span was in average cases the most economical in the conditions prevailing in that province. For the corresponding high-level bridges, the best ratio was about 1 : 4.

The one fifth of span ratio was adopted for the Andura bridge (described in the paper) over the same river as the Wagholi bridge and a few miles down-stream and also for the Khiroda and Manegaon bridges over the same river. It will be seen that the cost per square foot of elevation of the Wagholi bridge was nearly 50 percent higher than that of the Andura bridge and, although the change in the rise-span ratio was not solely responsible for the cheaper cost of the latter, it was undoubtedly an important factor.

The flat arches at Wagholi were adopted against some opposition because of the mistaken theory that one of the ruling considerations in submersible bridge design is the necessity to offer the least possible obstruction to the river. Afterwards, the views of more experienced designers prevailed, namely that obstruction was a factor which should be analysed and not treated with unscientific awe.

The Author has rendered a great service to the profession by recording the details of such an analysis in his paper but he has not commented on the practical application of his rules and, in his summary, has arrived at certain conclusions which are not now, I think, generally accepted by many engineers interested in this type of work.

The Bara-Rewa design (described in the paper) was never repeated in the Central Provinces, though there was another small bridge constructed at the same time to a similar design. These bridges were afterwards adjudged both expensive and ugly and later experience confirmed that, for conditions such as those met with at the Bara-Rewa, encased girders were much cheaper and more suitable.

The Bhandara foundations gave much anxiety. Light concrete cylinders such as those shown in the design are, I believe, now regarded in the Central Provinces as definitely *not* suitable, if rock is more than 20 to 25 feet below the river bed. Other requisites are that the bed must be composed of sand or similar material and the rock strata below must have vertical fissures or cracks or be fairly soft.

I understand that this design was adopted at the Purna bridge recently constructed or to be constructed near Edlabad in the Bombay Presidency. I would be interested to hear details from any member who knows about this bridge.

At Bhandara it was found that it was impossible to keep the light concrete cylinders truly vertical when they were sunk to depths of 35 feet or so and it is only because the Wainganga is a relatively slow-moving stream at Bhandara that the bridge may be regarded as safe. It is impossible to drive piles in the manner shown in the design through a sloping cylinder 35 feet deep—I need not stress the point in the presence of engineers.

I think the Author of the paper had no personal experience of the construction of these bridges or he would have recorded his warnings against accepting the designs for all cases.

With regard to the Mandla bridge referred to in the paper, it must be remembered that only 3 of the 80 spans were damaged but one abutment had been washed away and the road was badly damaged in several places. The repairs of this relatively small damage cost *more than three times the original cost of the bridge*.

The flood that damaged this bridge, was the highest recorded in the century 1826-1926. It destroyed two railway bridges further down-stream of the same river and many persons think that the submersible bridge stood up wonderfully well under the abnormal conditions of that time. When the repair work was finally decided on, many Central Provinces engineers recorded their opinion that the design adopted was needlessly expensive and a good example of panic engineering.

Any one who has designed bridges has only to look at the drawing (Fig. 4) in the paper to arrive at his own conclusion. We learn by our mistakes, but this job was more than a mistake and I had never expected anyone to refer to it except as a warning of how *not* to design, unless in a panic.

With regard to some of the flat-slab designs described in the paper, I have no personal knowledge of the particular bridges mentioned but there are members present whom I have heard talking of the knocking and vibrating of some of their slabs in floods. In similar designs elsewhere, I have myself noted similar defects.

3. The Author has not referred to the very difficult problem of the design of the abutments and wing-walls for submersible bridges, a matter over which there was in the past, considerable difference of opinion among some engineers.

The practice now generally followed is to omit wing-walls beyond abutments altogether, or practically so, and to construct "land spans". When the river is in flood and the bridge submerged, any obstruction at the ends sets up dangerous eddy currents which attack the river banks.

The designers of the "flat-arch school" of the early days who laid such great stress on avoiding obstruction as far as possible in the river itself, seem to have given no thought to the obstruction caused by the

abutments and wing walls in the approaches and yet the common experience is that the submersible bridges constructed in the pre-cement-concrete period were more frequently damaged at the ends than elsewhere—in fact, there are only two or three recorded cases in the Central Provinces of such bridges damaged elsewhere than at the ends.

When site conditions require large-arch spans at the ends of bridges, the question of friction abutments should be investigated. Another solution is to make "land spans" of shorter length but so constructed as to take the unbalanced thrusts of the main spans. Sometimes it pays to make abutment piers well away from the banks, as in the Tilwaraghat bridge (see paper read by Mr. A. W. H. Dean, Vol. 239 Session 1934 of the proceedings of the Institution of Civil Engineers, London).

4. With regard to the general conclusions stated in the last paragraph of the paper, it may be observed that it is not often possible to choose the site that is the most suitable from the engineering point of view, as the site is nearly always fixed, within narrow limits, from considerations of trade routes and other factors.

Too great stress can be laid on making spans "long enough and high enough to pass all floating debris". In actual design, the size of the spans is generally fixed from considerations of cost according to Waddell's well-known rule that the cost of the foundations should, as far as possible, equal the cost of the variable portion of the superstructure.

The height of the bridge is fixed, nearly in all cases, by the physical conditions of the banks as Author himself has so well described in the paper.

The temporary collection of debris is not the serious matter imagined by persons with limited experience of this type of bridge. There are some hundreds of submersible bridges in the Central Provinces of small span (20 to 40 feet) which regularly collect debris during floods but which never come to any harm on this account.

I believe some experiments are being carried out at the Irrigation Research Station at Poona on the lifting effect of floods on bridge slabs. Some of the superstructures shown for the slab bridges in the paper are on the light side and reference has been made to the pounding and vibration experienced in bridges having similar slabs.

There is a case on record where concrete slabs, weighing 15 tons each were lifted off a bridge under construction during a flood and deposited undamaged 70 feet or so down-stream. The lifting force can be lessened by suitably "nosing" the up-stream and down-stream faces of slabs (one case is referred to in the paper) and a good deal of experimental work has been done recently in this direction, so that it is, I believe, now regarded as good practice to have a particular kind of "nosing" on all flat-slab bridges.

5. The Author has not touched on many problems which are still engaging the minds of designers of submersible bridges. Among these may be noted the allowance to be made for buoyancy in piers and abutments;

the provision to be made for expansion joints (no such joints have been provided in several long *arched* bridges in the Central Provinces and there are no cracks visible, while bridges erected with expansion joints in some cases show heavy cracks in the pavement); the cushioning required over arch crowns; the elimination of silt deposits in the approaches; the necessity for sloping the formation at the ends to avoid rock-cutting in approaches; the provision of vertical transition curves, whether in the bridge itself or in the approach cuttings and many similar matters. Some of these problems are discussed in Mr. Dean's paper (referred to already) and the accompanying correspondence.

The question of cushion in these slab and arch designs is important. Some engineers hold that in hot dry climates, the blows on naked, rigid concrete structures from iron-tyred cart traffic tend to destroy the crystals in the concrete itself and may, in certain cases, lead to disintegration as has certainly happened after 20 years or so of such traffic over insufficiently cushioned lime concrete arches in the hot dry areas of Berar.

I do not quite understand the remarks of the Author on piers being safe, even if the resultant force falls outside the middle third. If the up-stream masonry faces crack, brush-wood and silt are forced into the joints and a time comes when there is danger of failure due to sliding as occurred in one case of a dam in the Central Provinces many years ago. In that case it was held that failure was due to taking the weight of silt laden water as 62.4 pounds per cubic foot instead of 64 to 68 pounds depending on the kind of silt in the river. I note 62.4 pounds is taken in the paper.

The Author is the engineer of a contracting firm and he has naturally had to confine his remarks to bridges built by his own firm.

He has failed to realise the historic origin of the submersible bridge in India which has grown from the causeway through the two very notable pre-war submersible bridges over the Nerbudda at Mandla and Khalghat, both built by the same Central Provinces Public Works Department Officer, Mr. H. B. Learoyd.

Although I have commented at some length on points of design not brought out fully in the paper, I feel I cannot sit down without congratulating the Author on dealing so ably with the very many more numerous and equally important points described in his paper. His analysis of stability factors is much in advance of anything I have so far seen in print and, although I do not agree with all his conclusions, the analysis will undoubtedly be of help to those interested in the subject.

I feel the Author has been hampered through not having been associated, during construction, with many of the bridges described by him but nevertheless, he has produced a paper which is worthy of this Congress and which will be of very great benefit to the profession.

Mr. Mahapatra (Cuttack):—There is only one point I would like to say in connection with the shape of piers. At page 6 (i), the Author has suggested that the best shape of a pier should have a rounded front and tapered end. But though the shape of an entrance does not affect the area

subjected to pressure, it greatly influences the velocity of discharge and thereby modifies the pressure due to static head. An opening with pointed piers resembles a bell-mouth and gives the maximum co-efficient of discharge with the minimum resistance to flow; for such an opening Thomas Box gives 0.96 as the co-efficient of velocity and, as already mentioned by the Author, Gibson's formula gives the co-efficient of 0.125 for computing pressures due to velocity, formation of eddies and friction. Therefore, I would suggest that the front of a pier should be pointed and have the shape of a gothic arch instead of being rounded to give the best result.

Mr. A. Nageswara Ayyar (Madras):—We are indebted to the Author for the lucid way in which he has enunciated the main principles governing the designs of submersible bridges. Often-times we see designs of submersible bridges being made similar to ordinary high-level bridges, although the stresses developed in the former are far more severe than in the case of the latter, and the paper under discussion will, we are sure, make designers careful in designing submersible bridges.

In the case of submersible bridges of the type described in this paper, it seems to me the saving in cost that can be effected by adopting the type will not be worth the risk involved. It is common knowledge that it is at the time of the highest floods, that large floating bodies such as big trees, hayricks etc. come. When the bridge floor causes obstruction near to the level of the highest flood, it causes the floating bodies to obstruct the ventway and present a very large surface of obstruction to the flow of water. This is especially the case when a forked branch of a tree gets entangled and in course of time collects further rubbish. In Madras, several old arch bridges which had been serving well for several decades, had given way on account of these causes.

The matter is not so serious when the foundations are rocky, but when the bridge is founded on sand or in clay, the obstruction caused, causes considerable scour, and exposes the bridge to serious risks. Hence, I think, submersible bridges should be designed as vented causeways so that all floating bodies which will come only in high floods and will lie in the surface will pass over the bridge without causing harm.

If the river goes in well-defined banks and does not have much overflow, it is very doubtful if submersible bridges will, at all, reduce the cost substantially. If, on the other hand, the river overflows the banks, and a substantial portion of the water flows over the banks, as happens in most parts of India, at least in South India, the bridge can easily be raised above the High Flood Level. (The real cost of the high-level bridge is due to the land spans, a considerable number of which is required to discharge the water owing to the shallow depth). The approach road can be sloped to meet the bank and the road taken at the level of the bank, so that in times of highest floods the approach roads may act as waterway. I had myself designed and executed several bridges of this type, and they have been serving for well over a decade. In one case, a high-level bridge designed to pass the whole discharge was estimated to cost Rs. 5 lakhs. This was re-designed as above described, and executed at a cost of Rs. 89,000/- only, and the bridge has been standing quite well for a decade now. The bed of the river is only sandy and the foundations have been taken only to a depth of 20 feet without any floor, and there

has been no danger. The design of a submersible bridge was also thought of at the time, but the reduction in cost by reducing the height of the bridge was quite negligible, and hence we didn't adopt it.

It is not known if, in the case of the Bhandara Bridge, the extra cost of raising the bridge above high flood level but keeping the approach roads submersible, had been worked out. In Madras, a high level bridge with long submersible approaches is a common occurrence, and has been found to give good results. Where, however, the discharge of a stream is small and the water rises high owing to the backing of a main river to which it flows, there is no object in raising the bridge above the high flood level, as, under such conditions, there will be very little flow and the waters will be merely stagnant. The decking will, however, have to be firmly fixed to the piers to prevent uplift but permit expansion under temperature changes.

In the case of hand rails for these submersible bridges, there is a particular difficulty. Most of our bridges are in out-of-the-way places and we are not sure when floods will come. It is quite possible the railings may remain in place when floods come overnight and cause irreparable damage, or an over-careful subordinate may remove the railings in the rainy season when for several days the bridge may remain without handrails and be in a dangerous condition. It seems desirable that when such bridges are adopted, the handrails should automatically collapse when floods rise above the road, and be in position when the floods go down. A design to satisfy the above conditions has been worked, and is being adopted in a submersible bridge in course of construction in Madras. It is not very costly: the cost comes to Rs. 8/- per running foot.

Rai Sahib Fateh Chand (United Provinces):—The Author has done a great service to road engineers by bringing out this paper giving a lot of useful calculations and other information on submersible bridges on which so little literature is available in engineering text books or in departmental circulars of the Public Works Departments. But to judge the real utility of such bridges, it is very necessary to compare their cost with the bridges of full height.

I would particularly like to know from the Author on what item or items he considers economy to be possible in the case of submersible bridges. The first and the foremost consideration is whether any economy is possible in foundations. As the Author says, a submersible bridge has to carry besides the live and dead load, a very considerable horizontal thrust. No economy can, therefore, be effected in foundations. The road surface will have to be actually stronger in the case of a submersible bridge than in a high-level bridge to allow for the rush of water passing over it. This being so, the point is, under what conditions a submersible bridge will be more suitable. A little economy in the masonry of the piers and abutments or in the earthwork of the approaches does not mean much. If no funds are available or if the road is not of sufficient importance for a bridge of the full size, will it not be more economical to construct a raised causeway? I have constructed several such causeways with a few Hume pipes or with small openings of, say, up to 15 feet span at comparatively small cost. I will, therefore, particularly request the Author kindly to indicate

the directions in which saving can be effected in the case of a submersible bridge and also to suggest a solution of the difficulty and the risk involved due to the bridge being without any parapets at all during the floods when these are required the most. I tried iron posts with chains which did not stand the combined forces of the flow of water and timber and other materials brought down the stream. I then tried 6 inches high perforated cement concrete parapets with $4\frac{1}{2}$ inches wide openings after every $4\frac{1}{2}$ inches. This was successful in as much as it provided a check against a traveller losing his feet due to the velocity of the current. Erection of two or four "balli" posts at 30 to 40 feet distances with wire or rope on either side of the causeway proved very useful in protecting the traffic against the same danger. But this cannot be possible in all cases and the Author might perhaps be able to suggest some other devices to meet difficulties of the above nature both over submersible bridges and over raised causeways.

Mr. K. G. Mitchell (Government of India):—The chart at Figure 1 of the variations in water level at the site of the Bhandara bridge in 1928 and in 1929 shows that the bridge was sited at a level at which it could have been only overtopped twice in 1928 and once, or possibly twice in 1929. These charts are useful in determining the level of a bridge and in order to consider, having regard to the traffic, what amount of interruption can be allowed if there is a correspondingly large saving in the cost of the bridge. But what I want to ask Mr. Nilsson is whether he considers that these charts of observations, taken a year or two before a bridge is constructed, reliable, that is to say, if corrected for a maximum known high flood level, will they represent the general shape of the curve in the majority of flood seasons? In short, how much value does Mr. Nilsson attach to these charts?

As Mr. McKelvie remarked, the design of submersible bridges is a progressive science and we expect designs to reflect the experience gained. Mr. Nilsson has pointed out in connection with the Bara-Reva bridge that the underside of the spans was made smooth. That bridge was built in 1931, but, on the other hand, the Kalisindh bridge, which was built in 1934, was provided with a corrugated slab to reduce the dead load. I have heard it said that, at times of flood just before the Kalisindh bridge is drowned, very considerable vibration is set up owing to this type of construction and it would be interesting to know why, if a smooth soffit was considered necessary in 1931, it was abandoned in 1934?

As regards what Mr. Ayyar said about building high-level bridges and, for a time, providing lower approaches in order to save initial cost, this might be an ultimate economy, but until high-level approaches were provided, the cost of the high-level bridge would not be reflected in any public benefit. The fact is, I think, that the conditions in India vary, and in some places submersible bridges are absolutely necessary, while in others conditions are different. One of the earlier submersible bridges that I know of is that over the Narbadda on the Bombay-Agra-Delhi road. The river there is in a deep well-defined channel, the road level on the bridge being well below the banks. In dry seasons, it has the appearance of a high-level bridge and it is in fact only closed, I believe, for about 10 to 12 days in an average monsoon. But when it is topped, it may have as much as 20 to 30 feet of water over it and a high-level bridge would be very

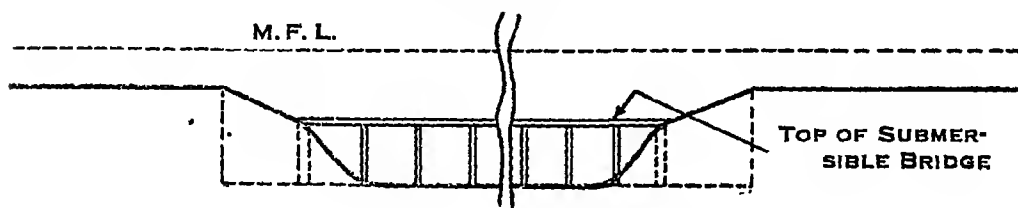
expensive. It is all a matter of the greatest possible service in the improvement of communications with limited resources.

As regards collapsible railings, the design of these has been very much improved, but there still remains the fact that when they are down, the bridge is, and looks to be, extremely dangerous. Stone bumping posts and other devices have been tried, but I do not think that an entirely satisfactory arrangement has yet been designed and it would be interesting to know if any one has any definite ideas on the subject.

There is one point on which Mr. Nilsson may be able to give us further information, and that is, on the design of approaches to submersible bridges. Where the approaches are at right angles to the river and are in cutting and the river carries considerable volume of silt, we frequently find that, when the flood has subsided, there is a heavy deposit of soft mud on the approaches, which renders them impassable until it has been cleared away which may take time and involves expense. I have seen, on the other hand, approaches to bridges and causeways more or less parallel with the stream and inclined in the direction of the flow which do not appear to suffer in this respect. This is natural, but I should be glad if Mr. Nilsson could throw any more light on the matter.

Mr. A. Lakshminarayana Rao (Madras):—I find that in the Paper, information is not given about the estimated cost of high-level bridges at the same site, so that we may be able to gather whether the construction of submersible bridges was economical or not. It is found in some of the given cases, the cost is as high as Rs. 600 per running foot. Ordinarily, bridges cost Rs. 300/- to Rs. 500/- per running foot. For submersible bridges the cost of Rs. 600/- per running foot is not economical. One of the peculiar features of the design is the obstruction to the waterway. If we look at the Bhandara Bridge, we find one third of the waterway is obstructed. The cross-section has not been continued to show that the construction of submersible bridge at the site was economical. Taking for example one of the bridges, the Bhandara Bridge; if a bridge had been built with higher roadway, the cost would not have been very much more and the structure would have been nearer a *pucca* bridge. One particular point I wish to make in this connection is that when we are designing a submersible bridge, the main principle to be observed, should be that it must be distinctly cheaper than a *pucca* bridge. If a submersible bridge at any particular site exceeds in cost by more than 40 per cent to 50 per cent from that of *pucca* bridge, then it is not much use going in for a submersible bridge. If the Author would give more details about this relative cost aspect, it would be very illuminating. I constructed one submersible bridge on a stream in Cuddapah District whose typical cross-section is shown in sketch 1 below. The submersible bridge cost one lakh and a *pucca* bridge in the same locality was estimated to cost three lakhs.

SKETCH NO. 1.



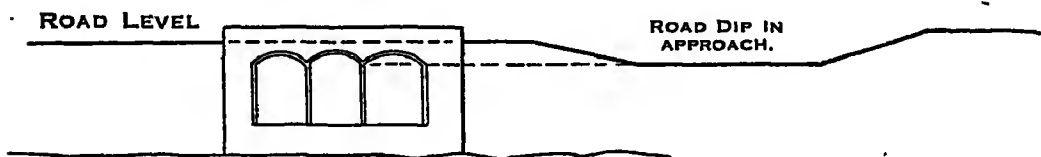
I only submit that in the design of submersible bridges, it is the cost of the bridge that matters and not any other consideration.

Another alternative to a submersible bridge design, I submit, will be, the provision of a high road dip in the approaches of the bridge. Supposing we have a running stream, inundating on either side for miles and miles; it may be stated that the number of spans to be allowed for a *pucca* bridge would increase the cost terribly. This is the chief objection raised against *pucca* bridges.

As against submersible bridges, the length of waterway to be provided in such cases is so great that the cost will be tremendously high. In the case of this bridge, constructed in this particular place (points out on the board), here a small road dip is allowed in the approach. (See sketch No. 2 below). This dip would not obstruct traffic, but would act as a safety valve in flood season. I submit it has to be considered whether a *pucca* bridge with a spillway in the approach, at a level which will not stop traffic, would not be more economical than a submersible bridge. If after considering all these aspects, it be found that the cost of a submersible bridge is 40 to 50 percent of that of a *pucca* bridge, and if it be found that a *pucca* bridge would not be more economical, we have to go in for a submersible bridge.

As my friend, Mr. Ayyar had put it already, it has been worked out in the Madras Presidency, that in many places where some engineers had designed submersible bridges, *pucca* (high-level) bridges would not exceed in cost by more than 30 percent from that of submersible bridges. The prime factor is to decide on the most economical bridge and the designs should not be based on any other consideration.

SKETCH NO. 2.



Mr. G. B. Vaswani (Karachi):—There are two kinds of rivers, some are inundation rivers and others are perennial rivers. In the case of perennial rivers, when any bridge is to be constructed, it is better to have a bridge for high water level and specially where heavy type of business traffic is taken over it.

In the case of inundation rivers, it is not necessary to provide arches for the whole length of the river, because anyway, the bridge is to be flooded, whether you provide arches or no arches.

In Karachi we have got one inundation river which flows with a great force during the time of the flood. We found that if we constructed high level bridge so that people could cross it at all times, the cost was too much. Therefore, we decided to provide a low level causeway with openings and 24 inches diameter pipes in the sides so as to break the force of the under-

currents and also to be passable over the portions where water stood throughout the year. This reduced the cost considerably.

In my opinion this is the best way of reducing the cost.

Mr. D. Nilsson (Author):—Mr. McKelvie's comments were the first ones and I thank Mr. McKelvie for the interesting remarks he has made. I think we all are indebted to him for having taken the trouble of printing these remarks for us.

I must first protest against his stating twice that I have no personal experience of the work concerning which I have written. All the bridges, except, of course, the original part of the Mandla Bridge, were designed and built by my firm during the time I have been either Chief Assistant or Chief Engineer; and the bridges mentioned are not all the submersible bridges in which I have been interested. Mr. R. P. Mearns was our Chief Engineer during the construction of the bridges in the Central Provinces which particularly interested Mr. McKelvie and these bridges, I think, not only formed my first experience of Reinforced Cement Concrete submersible bridges, but that of Mr. McKelvie also. He may be interested to know that all the engineers who were resident on those works are still on my staff.

Mr. McKelvie thinks that the graph of flow on the Tapi and Purna rivers would have been better than the one in the paper. I quite agree, but unfortunately, as he himself has pointed out in his remarks I am only a contracting engineer and have to use the material I have available. However, I think that the graph in the paper illustrates very well what I intended to show i.e., the very high floods and their rapid rise and fall during the monsoon.

Here I should reply to one of the points raised by Mr. Mitchell. He asked whether generally such charts were available for rivers when bridges had to be built. Unfortunately they are very seldom available and the charts shown in the paper were obtained from figures kept by our own engineers on the job. If charts were available, one could see from the chart whether a submersible bridge would be suitable or whether it was necessary to construct a high level bridge.

I am sorry if I took it for granted in the paper that nobody would build a submersible bridge if a high level one was cheaper (Laughter). I am sorry also if I appear to have given, as Mr. McKelvie says "a mere description of actual structures which may not represent latest accepted practice". I thought I had given examples, each of which illustrated some detail of design.

Anyway I hope they are not all as bad as the impression given by Mr. McKelvie, for I have three under construction at the moment, but I do think that having criticised so much he ought to have given us at least one example of the "latest accepted practice", or as he says in para 2 (on page 30, (i)) of his remarks, at least one "example of the last word in design".

Mr. McKelvie says that the flat arches at Wagholi were afterwards regarded as a bad mistake, but he does not say by whom, nor does he give

a reason except that they were based on the mistaken theory that a submersible bridge should afford the least possible obstruction to the river. Do not let yourselves be misled by this. The obstruction offered is of great importance and it must be carefully considered in the design. Even Mr. McKelvie contradicts himself sufficiently further on to admit this by saying "the views of more experienced designers prevailed namely that obstruction was a factor which should be analysed". I wish he had named those "more experienced designers". You can build a dam to completely obstruct the flow, then the horizontal forces are very great and you make a correspondingly large base. In a submersible bridge the horizontal forces are much less and the base on which it stands is also much less but the two must be designed to suit each other so that the structure is safe. Dealing with the effect of this obstruction is the main point of my paper.

If you look at figure 3, you will see that the Wagholi bridge is founded on piles. When designing the bridge, it was not known that the ground was so hard that only comparatively small penetration of the piles could be obtained. Further, it was also not intended to dig down to the depth shown and fill in with weak concrete round the piles which incidentally added much to the cost. If you imagine the piers standing on the pile caps supported on about 35 feet long piles in ordinary piling ground, you will I think agree that it was sound practice to reduce the obstruction and resulting horizontal forces as much as possible. The objections to flat arches are of course the heavy abutments required if rock is not close to the surface and the extra cost of the arches due to the high arch shortening and temperature loads which occur.

The Bhandara foundations were criticised but I do not think that at the time of building this bridge the good points of the design were properly appreciated, nor apparently are they now. Insistence need not have been made on sinking the cylinders down to rock nor need they be so truly vertical as he suggests. The cylinders are not intended to carry weight, the piles do that, what the cylinders do is to enable the piles to be braced at a very much lower level and formed into a solid group, and the cylinder also protects the piles where they are most liable to attrition. Further, and most important of all, is that, in spite of what Mr. McKelvie says, it is a very sound foundation and at the same time comparatively cheap.

Reference is made to the Purna Bridge. This was designed to my instructions for the Bombay Government and built by Messrs. Hindustan Construction Company and I have already given Mr. McKelvie a copy of the drawing. The design is very similar to the Bhandara Bridge except that here the cylinders are sunk through sand and shingle and the piles driven into what is called "mann" and silt. I believe that some trouble was experienced there also owing to the wells being sunk unnecessarily deep. The cylinders should not be sunk into difficult ground they should sink comparatively easily and when the sinking becomes difficult the piling should be driven and the cylinders concreted. The sinking is not meant to go into such ground that the cylinder is capable of carrying the load itself.

It is stated that the repairs at Mandla Bridge cost more than three times the original cost of the bridge. That I do not know, but the total cost of the repairs including various other odd jobs was Rs 2,12,000/- so

that the old bridge must have cost less than Rs 70,000/- though it is about 1,900 feet long, or about Rs. 37/- per lineal foot. Well, I am sure glad I did not build the old bridge (Laughter). Mr. McKelvie might, I think, have pointed out that the repairs did not only consist of replacing a part of the bridge where the water was swift and about 15 feet deep, but the repairs included widening of that part of the bridge and replacing all the old lime concrete spandrel fillings by cement concrete and many other items I cannot remember. Also, no more trouble has been experienced with that bridge. Mr. McKelvie is surprised that anybody should refer to this bridge except as a warning of how not to design and if he will refer to the paper again he will see that that is exactly what I have done.

Mention is made of knocking and vibration in the flat slab design. Details regarding this would have been of real service and interest and I trust that these, if they can be substantiated, will be communicated to the Roads Congress.

Mr. McKelvie also gave a very interesting sketch and remarks on the rounding of the edges of slabs. I think his suggestion is very good and I hope he will not mind if I adopt it on some bridges I am doing just now.

Mr. McKelvie draws attention to a number of points which I have not touched on particularly, but most of these are points which will arise whether the bridge is submersible or not and I have tried to confine myself to those things which occur only because the bridge is to be submersible. However, buoyancy does concern submersible bridges and attention is drawn by him to a dam which failed because the silt laden water was taken at 62.4 pounds per cubic foot instead of 64 to 68 pounds per cubic foot. In the one case, there was $2\frac{1}{2}$ percent and on the other case 9 percent difference in weight and it seems likely that there were also other contributory causes of failure. Generally speaking for a bridge being designed on reasonably safe factors, 62.4 pounds per cubic foot will be quite safe.

He also brings up the question of the abutments and he particularly refers to land spans. This might apply to either submersible or high level bridges and will depend upon the site and especially the cross section of the river. For example, if the river has steep banks it will be best to have the abutments in the bank, but if the cross section is dish-shaped a land span may be both cheaper and better.

Mr. McKelvie says too great stress can be laid on making spans long enough and high enough to pass all floating debris and he points out how lucky they have been in this connection in the Central Provinces. Nonetheless, I suggest you make allowance for as large openings as possible allowing, of course, for the necessities of the site and reasonably economical design. It is impossible to lay down hard and fast rules, all the various points must be kept in mind and the best possible compromise made, without ever sacrificing strength or stability.

Mr. Mulapatra has brought out quite a good point. He has suggested that an opening with pointed piers resembles a bell-mouth and, therefore, gives an increased discharge and consequently less resistance. This is of course true for very small spans but where spans are large the effect would

be negligible. It must also be remembered that a bell-mouth with rounded sides will give a larger discharge than one with straight sides and therefore it looks as if the pier with a rounded up-stream cutwater will give the best shape.

Mr. Nageswara Ayyar suggests that the risk of submersible bridges is not worth the saving. I have tried to point out in my paper that there should not be any risk if the bridge is designed properly. He suggests that a low causeway should be used as there will not be much saving if a high causeway is designed. Several other speakers suggested the same thing. I think Mr. Vaswani suggested that the causeway should only have a few arches in the centre and the ends should be solid. I do not think these gentlemen have had experience of a real type of submersible bridge. What they are after is a bridge where the ordinary flood level is the same as the maximum high flood level. They must realise the difference between ordinary flood level and the maximum high flood level in rivers with flood charts such as I have shown. There a bridge is required which comes over the ordinary high flood level, but under the maximum high flood level. The maximum high flood level overtopping the bridge only stops traffic for a few hours during one or two days in the monsoon.

Mr. Ayyar has also spoken of hand rails in outlandish sort of places where there would be nobody to collapse them before a flood and Rai Sahib Fateh Chand has also referred to this point. In many places only small wheel guards are used and no railings. In the paper I mentioned the bridge over the Narbadda River where the railing collapses by itself during high flood but has to be lifted up again after the flood has subsided. On one bridge in the N. W. F. Province, timber posts are let into holes in the deck. These form quite a useful and efficient railing which, during floods, offers little obstruction and, if broken, can easily be replaced.

Mr. Mitchell points out that in 1931 we built slab bridges with flat bottoms and later in 1934 we built slab bridges with corrugated bottoms. The flat bottom is of course much better but the corrugations in the design shown are extremely small and it was thought that their effect would be negligible whereas the design is very efficient and economical.

I shall be very glad to hear particulars of the suggested vibration which occurs in these slabs and to know whether there is really anything in the suggestion that matters, or whether the vibration is just a slight shaking which very often is experienced in many bridges during high flood.

Mr. Lakshminarayana Rao suggests that in some cases high level bridges would have been cheaper than submersible bridges but I can assure him that that is not the case. It is not merely the cost of raising the piers that makes the difference because there is a tremendous difference between the whole submersible bridge and high level bridge design. The length of a low level bridge may be less than half that of the high level bridge and that will obviously give an enormous saving. He thinks that the obstruction on the Bhandara Bridge is very great—almost one third, but he should remember that, during floods, practically the whole of the sand in the river bed will be scoured out. He further suggests that the high level

bridge, with spillways at either end, might be better and cheaper. Whether this would be so, is a matter for investigation. Every bridge must be examined from every possible point of view and it is quite impossible to standardize on any particular type. It will always be a compromise of some sort but when you do compromise, keep it on the safe side.

Mr. McKelvie in his remarks at the end complains that I have failed to realise the historic origin of the submersible bridge, but I regret I was not dealing with that aspect at all. Perhaps he would be good enough to read a paper himself on that subject for next session. If so, I hope he will not forget the submersible bridges in Africa and Australia where I believe a very large one was built as long ago as 1896.

Mr. P. V. Chance (Chairman):—I wish on behalf of the members to thank Mr. Nilsson for his most interesting paper. Many of the bridges were constructed in the Central Provinces and they are standing well and have given no trouble. We have been discussing this morning the necessity for reporting failures but these bridges are successes and I do not think there can be much wrong with the theory on which they were designed.

There are one or two points I may mention. Mr. McKelvie has referred to the research on slab bridges. The slabs of a small bridge were washed away and experiments on the uplift on such slabs have not been completed but there is good reason to believe that the cause of the damage was due to green masonry in the piers rather than any exceptional hydraulic force. Mr. McKelvie has also referred to the reputed high specific gravity of the water in the Central Provinces and its effect on a dam. The dam failed owing to the section being insufficient to withstand the normal pressure. After the failure, an explanation was given that the water carried such large quantities of silt that the pressure was abnormal. Most of the engineers concerned did not accept this explanation.

If submersible bridges are constructed at or a little below natural bank level, the silting of the approaches which sometimes takes place as pointed out by Mr. Mitchell would be largely avoided. It is, of course, necessary, as Mr. Nilsson has stated, that the formation should not be higher than the banks so that approaches in filling may be avoided but the ideal position is just below the natural banks.

In conclusion I have to thank Mr. Nilsson for his most interesting paper and also to thank those members who gave us the benefit of their views on it.

CORRESPONDENCE.

I. Comments made by Mr. Dildar Hosain (Hyderabad-Deccan) on Paper No. I. by post

In the case of Wagholi Bridge, the substratum is shown to be clay below the sand, whereas in the case of Andura Bridge, stiff clay is shown to lie below clay and sand mixed with clay. In the former case pile foundations

tions have been adopted whereas in the case of the latter bridge ordinary foundations have been adopted.

It would be interesting to know how the relative bearing powers of the two types of clay were determined before deciding upon the particular design and whether the chances of a scour taking place in the case of Andura Bridge where the foundations rest entirely in clay have been kept in view.

2. In the case of Bara-Rewa Bridge, the decking consists of beams and slabs. I would like to know whether the beams were anchored down with the masonry of the piers, and if so, to what depth, as in such cases the impact from floating trees might sometimes be so great as to dislocate the entire deckway.

3. The design of Kalisindh Bridge is shown to consist of four or five spans designed as continuous beams. Does this mean that each set of 4 or 5 spans is treated in this manner? The word 'or' does not give the precise idea.

It is said that the slab was corrugated near the centre in order to reduce the dead load. Is it to be understood that the reinforcement of the slab was also bent to conform to the proposed corrugations. If not, it implies that the cover at the crown of the corrugations was reduced, and again increased at the trough, which means that there is hardly any appreciable reduction of the dead load.

4. The Tapti Bridge is said to be similar in design to the Andura bridge and is said to have been overtopped by a flood of 33 feet. This represents an application of a dynamic load of nearly a ton per square foot of the bridge surface. I would like to know whether the design of the arch has taken this also into account.

5. It is seen from the accompanying table that the difference between the high flood level and the bridge road level varies for 0.25 feet to nearly 20 feet in the case of the different bridges. It would be useful to know why in the cases of low submergence, it was not considered advisable to design an insubmersible bridge.

Particulars.	H.F.L.	B.R.L.	Spans.	Difference (in feet)	
				between H.F.L. & B.R.L.	
Bhandara Bridge ...	110.00	104.75	18 V. 86'-0"	6	
Wagholi Bridge ...	66.25	53.75	8 V. 50'	12 50	
Mandla Bridge ...	...	Information not given		...	
Andura Bridge ...	788.20	773.80	8 V. 56'-3"	15	
Bara-Rewa Bridge ...	100.00	79.90	7 V. 34'-3"	20 nearly.	
Kalisindh Bridge ...	84.90	84.65	25 V. 33'-8"	0.25	
Monaguni Bridge ...	44.75	41.79	5 V. 33'-4"	3	

II. Reply by Mr. D. Nilsson to the comments of Mr. Dildar Hosain, on Paper No. I by post.

Mr. Dildar Hosain asks regarding the Wagholi and Andura Bridge foundations, as to why piles were decided upon in the one case and open foundations in the other. I cannot remember the exact conditions under which these were settled, but I presume that the information regarding the river bed was rather scanty as apparently, judging by the small penetration obtained by the piles, open foundations would have been just as suitable at Wagholi as at Andura Bridge

The deck of the Bara-Rewa Bridge was not anchored down to the masonry piers but had a layer of bituminous felt between the deck slab and the pier cap. If the drawing is examined, it will be found that this deck is extremely heavy and amply safe against any impact from floating trees.

I am sorry that the wording in my paper has not been quite clear, but as regards the Kalisindh Bridge there are five sets of spans of 4 slabs continuous to make up the total of 25 spans

As regards the arrangement of the steel with the corrugations, this is quite simple as the steel is placed in the troughs of the corrugations as if they were a series of beams and ample cover is obtained everywhere.

Mr. Dildar Hosain suggests that because the Tapti Bridge is overtopped by 33 feet of water it has to carry a load of nearly a ton per square foot. He seems to forget that the water pressure is the same in all directions and that the water is under the bridge as well as over the bridge and there will be no actual downward load on the bridge on account of the depth of water by which it is submerged.

As regards the difference between the high flood level and the bridge road level, this is fixed by the conditions at the site and also requirements of the roads. Generally speaking, the road level has been fixed by the Public Works Department for us.

PAPER No. J.

Rai Bahadur S. N. Bhaduri (Chairman):—The next discussion is on Paper, J, "Designs for Reinforced Concrete Bridges of short spans for Indian Roads". I would call upon the Author of the paper to introduce his Paper.

The following paper was then taken as read :—

PAPER No. J.

DESIGN OF REINFORCED CONCRETE BRIDGES OF SHORT SPANS FOR INDIAN ROADS

BY

BRIJ MOHAN LAL, I.S.E.,

Executive Engineer, Punjab P. W. D.

1. *Object.*—In the present age of road development, old roads are being improved and new ones being constructed in every part of India. All this road programme necessitates the remodelling of old bridges and construction of new ones, since bridges form the most important links in the chain of highway communication. There is however at present no uniform practice in their design, and every engineer has to choose and adopt his own data and formulæ when he is confronted with the task of building them. The Indian Roads Congress has performed a valuable service to Road Engineering in India by publishing "Standard Specification and Codes of Practice for Road Bridges in India". If these are adopted by all Provincial and State Governments, it will result in uniformity of strength and width of bridges throughout the country. Although the large bridge over the big rivers is a rarity, the construction of the short span bridge is of every day occurrence. The object of this paper is to standardise the design of bridges of spans upto 40 feet based on the Specification and Codes of Practice referred to above to save road engineers the trouble of having to design them *ab initio* every time they have got to construct one.

2. *Types.*—As the reinforced concrete slab is now-a-days the usual type of construction, the following types have been considered in this paper :—

(a) Reinforced concrete slabs for spans upto 20 feet.

(b) For spans 10 feet to 40 feet :—

 Rolled steel Beams carrying Reinforced Concrete slabs.

(c) For spans 15 feet to 40 feet :—

 Reinforced concrete T-Beams and slabs.

3. *Width of Roadway.*—The practice in the Punjab Public Works Department, Buildings and Roads Branch, is to provide a width equal to total formation width of the road concerned between wheelguards for bridges upto and including 8 feet span, and a width of 20 feet beyond 8 feet span. In the Standard Specification too, a width of ten feet has been adopted per lane of traffic *vide* para A 3 on page 3. Therefore, for bridges of more than 8 feet span, a width of 20 feet capable of carrying two lanes of traffic is sufficient for all roads in the country outside Municipal limits. The formation width of roads in the Punjab is usually 32 feet, and this width is good enough for three lanes of traffic.

4. *Live load*.—Designs in this paper have been made for The Indian Roads Congress Standard loading *vide* para B 3 on page 7, as most of the bridges generally required lie outside Municipal limits and Industrial areas.

5. *Impact factor*.—The following formula is recommended in the Standard Specification *vide* para B 4

$$I = \frac{1}{2} \times \frac{65}{45 + \frac{L(n+1)}{2}} \text{ with a maximum value of } 0.50.$$

Where n = the number of traffic lanes and L is the loaded length of span giving the maximum stress in the member under consideration.

For a span of 8 feet and 3 lanes of traffic (32 feet roadway) this works out to

$$\begin{aligned} \frac{1}{2} \times \frac{65}{45 + \frac{8(3+1)}{2}} &= \frac{1}{2} \times \frac{65}{45 + 16} \\ &= \frac{1}{2} \times \frac{65}{45 + 16} = 0.53. \end{aligned}$$

Therefore for all spans upto 8 feet, a maximum value of .50 should be used. For a span of 15 feet and 2 lanes of traffic the impact factor will be

$$\begin{aligned} &= \frac{1}{2} \times \frac{65}{45 + 15 \times \frac{(2+1)}{2}} \\ &= \frac{1}{2} \times \frac{65}{45 + 15 \times \frac{3}{2}} \\ &= .48. \end{aligned}$$

Therefore for spans upto 15 feet too, an impact factor of 0.50 is good enough.

Table I gives the permissible impact factor upto 500 feet span. Figure No. 1 shows the same result in the form of a curve. In the following designs the figures arrived at above have been used for impact factor.

6. *Design of Reinforced concrete slabs*.—Chapter D of the Standard Specification and Codes of Practice for Road Bridges in India deals with Reinforced Concrete bridges and its recommendations are based on the Indian Railway Standard Code of Practice for Reinforced Concrete Construction and the Code of Practice for the use of Reinforced Concrete in Building published by the (Imperial) Department of Scientific and Industrial Research, London. In these specifications, the stresses recommended for even the ordinary grade concrete are higher than those generally in use in this country at present. Table I on page 89 of the Standard Specifications shows these for 1:2:4 mix to be 750 pounds per square inch for concrete in bending, 75 pounds for shear, and 100 pounds for bond. The Modular Ratio has also been adopted as 18 instead of the usual 15. Stress for steel in tension has been recommended as 18,000 pounds per square inch (page 92 Table IV) instead of the usual 16000 pounds.

As the quality of cement and standard of work obtainable in this country has sufficiently improved recently, there appears to be no objection to adopting these for concrete road bridges in India and therefore designs have been worked out adopting the above stresses in this paper.

Table II of this paper gives the properties of reinforced concrete slabs of total thickness ranging from seven inches to fifteen inches as explained below

Column 1 gives total thickness of slab. It will be shown hereafter that it is not economical to use slabs of less than 7 inches total depth for road bridges, and therefore calculations have been made for total depths commencing from 7 inches and rising by half an inch to 15 inches.

Column 2 gives effective depth of each slab.

A cover of one inch and a half from the centre of main reinforcement has been assumed giving free cover of just more than an inch.

Column 3 gives the moment of resistance of one foot width of each slab. This has been calculated from the formula

$$M_R = Rbd^2$$

$$\text{where } R = pf_sj$$

$$p = \text{ratio of steel to concrete}$$

$$f_s = \text{tensile unit stress in steel}$$

$$j = \text{ratio of lever arm of resisting couple to depth}$$

According to standard practice.

$$p = \frac{\frac{1}{2}}{\frac{f_s}{nf_c} \left(\frac{f_s}{nf_c} + 1 \right)}$$

$$k = \sqrt{2pn + (pn)^2} - pn$$

$$j = 1 - \frac{1}{3}k$$

$$\text{where } n = \text{modular ratio}$$

$$f_c = \text{stress in concrete in bending}$$

$$k = \text{ratio of depth of neutral axis to depth } d$$

using the stresses adopted and above formulæ

$$p = .0089$$

$$j = .857$$

$$R = 137$$

Column 4 gives the area of steel per foot width of slab assuming

$$p = .0089$$

Column 5 gives the number of bars with spacing required for the area of steel in column 4.

Column 6 gives the actual area of steel used per foot width.

Column 7 gives the number of bars and spacing required as distribution steel as required by para D 22 (c) of the Standard Specifications. This distributing steel has been calculated from the tables given on page 43 of the Explanatory Handbook on the Code of Practice for the use of Reinforced Concrete in Buildings, published by the (Imperial) Department of Scientific and Industrial Research, by Messrs. Scott and Glanville.

Column 8 gives the weight of one foot width of slab assuming a weight of 144 pounds per cubic foot of reinforced cement concrete.

7. *Simply supported slabs.*—Table III gives the designs of simply supported slabs for various spans from 5 feet to 15 feet.

Take for example a span of 10 feet; assume total thickness of slab $10\frac{1}{2}$ inches with effective depth 9 inches. Effective span is 10.75 feet *vide* para D. 22 (a) of the Indian Roads Congress Standard Specification. Dead load bending moment assuming a wearing coat of 3 inches thick plain cement concrete at 140 pounds per cubic foot is as below:—

Weight of one foot width of $10\frac{1}{2}$ inches slab ...	126 pounds
Weight of three inch thick cement concrete wearing coat...	35 pounds
Total ...	161 pounds.

$$\text{Bending moment due to dead load} = \frac{161 \times 10.75 \times 10.75 \times 12}{8}$$

$$= 28200 \text{ inch pounds.}$$

Live Load.—The Indian Roads Congress Standard loading has been specified as follows in para B 3 on page 7 of the Standard Specification:—

0.34 ton per linear foot of each traffic lane plus a knife edge load of 6 tons for computing bending moments or of 9 tons for computing shears with the limitation that for computing bending moments the total distributed load on loaded lengths of 20 feet and under shall never be less than 6.8 tons per lane of traffic over the whole loaded length.

Impact factor for 10 feet span *vide* Table I of this paper is 54; a maximum of 50 per cent is however to be used.

Therefore bending moment per foot width of slab for live load is as below:—

$$\text{Due to distributed load} = \frac{.68 \times 2240 \times 10.75 \times 12}{8}$$

$$= 24500 \text{ inch pounds.}$$

$$\text{Due to knife edge load} = \frac{.6 \times 2240 \times 10.75 \times 12}{4}$$

$$= 43400 \text{ inch pounds}$$

$$\text{Total} = 67900 \text{ inch pounds.}$$

adding 50 per cent for impact.

$$\text{Total bending moment for live load} = 101800 \text{ inch pounds.}$$

Adding dead load bending moment, the total bending moment amounts to 130,000 inch pounds.

Referring to Table II, it will be seen that a slab of total thickness $10\frac{1}{2}$ inches is safe for a total bending moment of 130000 inch pounds.

5^(j)

Now test this slab for shear and bond stresses.

Shear.

This will be maximum at the supports.

Due to Dead load

$$\text{Slab} \quad 10.75 \times \frac{10.5}{12} \times 144 = 1356 \text{ pounds}$$

$$\text{Wearing coat} \quad 10.75 \times \frac{3}{12} \times 140 = 377 \text{ pounds}$$

$$\text{Total} = 1733 \text{ pounds}$$

$$\text{Reaction on one support due to above} = \frac{1733}{2} = 867 \text{ pounds}$$

Due to Live load distributed

Reaction on one support

$$\frac{.34 \times 10.75 \times 2240 \times 1.5}{10 \times 2} = 615 \text{ pounds.}$$

Knife edge load for computing shears is to be taken as 9 tons *vide* page 7 of the Standard Specification. Distributed on a width of 10 feet, this is equal to .9 ton or 2016 pounds on one foot width.

Adding 50 per cent impact this is equal to 3024 pounds.

Adding up, total shear amounts to 4506 pounds

Now $v = \frac{V}{bjd}$ *vide* equation (1) on page 108 of Standard Specification

$$j = .857$$

$$v = \frac{4506}{12 \times .857 \times 9} = 48.6$$

against an allowable stress of 75 pounds *vide* Table I page 89 of the Standard Specification.

Bond Stress.

$$\text{Bond stress, } u = \frac{V}{jd \sum o}$$

Where $\sum o$ = Sum of perimeters of the bars in the tensile reinforcement, [*vide* equation (3) on page 111 of the Indian Roads Congress Standard Specification and Codes of Practice.]

$$\begin{aligned} \text{Hence } u &= \frac{V \times b}{bjd \times \sum o} \\ &= v \times \frac{b}{o \times \frac{b}{\text{spacing of bars}}} \end{aligned}$$

Where o = Perimeter of one bar

$$\begin{aligned} \text{Hence } u &= v \times \frac{\text{spacing of bars}}{\text{perimeter of one bar}} \\ &= \frac{48.6 \times 5.5}{2.356} = 113. \end{aligned}$$

According to para D. 25 (a) on page 110 of the Indian Roads Congress Standard Specification and Codes of Practice, it should not exceed twice the appropriate permissible bond stress which is 100 pounds *vide* page 89 of that book. As 113 pounds is less than twice 100 pounds, the slab is safe for bond stress too.

It will be seen from Table III that a slab of 7 inches thickness is subjected to a bond stress of 192 pounds. As a greater part of the shear is due to knife edge load which will be 9 tons for a span of even one foot, it is clear that to keep the bond stress within permissible limits, any thickness less than 7 inches will not be safe for shear and bond stresses.

A detail of the slab for ten feet span has been shown in Figure 3.

8. *Slabs for continuous spans.*—It is frequently necessary to build bridges of multiple spans using continuous slabs. Table IV gives bending moments for live loads for intermediate spans and end spans. For purposes of easy calculations, bending moment for intermediate spans has been taken as $\frac{WL}{12}$ and that for end spans as $\frac{WL}{10}$.

Take for example 10 feet span.

Effective span too is 10 feet.

Intermediate span.

$$\begin{aligned} \text{Bending moment for distributed live load excluding 50 per cent impact} \\ \text{per foot width} &= \frac{6.8 \times 2240}{10} \times \frac{10 \times 12}{12} \text{ inch-pounds} \\ &= 15230 \text{ inch pounds} \end{aligned}$$

$$\begin{aligned} \text{Bending moment for knife edge load per foot width} \\ &= \frac{6 \times 2240 \times 10 \times 12}{10 \times 6} \\ &= 26880 \text{ inch-pounds.} \end{aligned}$$

$$\text{Total} = 42110 \text{ inch-pounds}$$

Adding 50 per cent impact this amounts to 63165 inch pounds.

A reference to Table II will show that a slab of 8 inches thickness has a moment of resistance of 69500 inch-pounds.

Assume a slab of 8 inches thickness.

$$\begin{aligned} \text{Bending moment for dead load} &= \frac{(96 + 35) \times 10 \times 10 \times 12}{12} \text{ inch-pounds} \\ &= 13100 \text{ inch-pounds.} \end{aligned}$$

$$\text{Total bending moment} = 76265 \text{ inch pounds}$$

Therefore a slab of thickness $8\frac{1}{2}$ inches with a resistance moment of 80600 inch pounds will suit.

End Span.

For an end span the total bending moment will be $76265 \times \frac{5}{8} = 93518$ inch pounds.

A slab of thickness 9 inches with a resistance moment of 92500 inch pounds will therefore suit.

Average live load per square foot has also been derived in this table from the total combined bending moments. These results have also been shown in a graphical form in Figure 2.

9. *Reinforced concrete slab supported on Rolled Steel Beams.*—It will be seen from Tables II, III and IV, that bridges upto 15 feet span simply supported and 20 feet continuous spans can be economically constructed using reinforced concrete slabs. For bigger spans it becomes necessary to use beams either of steel or reinforced concrete carrying timber, steel or reinforced concrete flooring. It is however now usual, as well as economical, to use reinforced concrete for the flooring. A combination of rolled steel beams and concrete slab therefore is a handy and convenient method in most cases. Designs have therefore been worked out in Table V for rolled steel beams for spans from 10 feet to 40 feet. Take for example a clear span of 25 feet between supports. For a clear roadway width of 20 feet the arrangement of beams shown in Figure 4 will be economical.

Design of slab.

For a continuous span of 5 feet 6 inches the total live load bending moment will be midway between those for 5 and 6 feet in Table IV *i.e.*, 34746 inch-pounds. A slab of 7 inches thickness will be safe for this. Similarly the cantilever projection of 2 feet 6 inches will have the same maximum bending moment as a 5 feet slab *viz.* 31582 inch-pounds. A 7 inches thickness is therefore safe for the cantilever portion also.

Design for Rolled Steel Beams.

Clear span ... 25 feet

Assume beam ... 20 inches by $6\frac{1}{2}$ inches at 65 pounds per running foot.

Effective span... 27 feet.

Dead load bending moment.

Weight of slab per square foot ... 84 pounds

Weight of wearing coat per square foot ... 35 pounds

Total ... 119 pounds per square foot.

Weight of beam = 65 pounds per running foot

Total weight carried

by one beam = $27 \times 119 \times 5\frac{1}{2}$ = 17600 pounds

Weight of beam = 65×27 = 1750 pounds

Total = 19350 pounds.

Dead load bending moment = $\frac{19350 \times 27 \times 12}{8}$

= 775000 inch pounds = 345 inch tons.

8 (j).

Live load bending moment for one beam.

Bending moment due to distributed load for $5\frac{1}{2}$ feet width

$$= \frac{.34 \times 5.5 \times 27 \times 27 \times 12}{10 \times 8} = 202 \text{ inch tons.}$$

Knife edge load bending moment

$$= \frac{6 \times 5.5 \times 27 \times 12}{10 \times 4} = 268 \text{ inch tons.}$$

Total live load bending moment = 470 inch tons.

Add 40 per cent. for impact *vide* Table I.

$$470 + 188 = 658 \text{ inch tons}$$

say 660 inch tons.

Adding dead load bending moment, the total bending moment amounts to 1005 inch tons.

Section modulus for a rolled steel beam safe to carry this bending moment assuming 8 tons per square inch as permissible stress for steel will be $\frac{1005}{8} = 125.6$.

Beam 20 inches by $6\frac{1}{2}$ inches at 65 pounds per running foot has a section modulus of 122.6 and will therefore be safe.

Table V gives the designs for rolled steel beams for spans 10 feet to 40 feet calculated as above.

10. Reinforced concrete T-Beam Bridges with slab.

Take clear span 30 feet.

Assume spacing of T-Beams as 5 feet 6 inches centres slab 7 inches thick and wearing coat 3 inches thick as in case and Rolled Steel Beam bridges.

Assume stem of beam 28 inches by 14 inches.

Weight per foot run :—

$$\text{Slab and wearing coat } 119 \times 5.5 = 655 \text{ pounds.}$$

$$\text{Beam 28 inches by 14 inches} = 392 \text{ pounds.}$$

$$\text{Total} = 1047 \text{ pounds.}$$

Say 1050 pounds.

Take effective span 32 feet.

$$\text{Bending moment due to dead load} = \frac{1050 \times 32 \times 32 \times 12}{8}$$

$$= 1,610,000 \text{ inch pounds}$$

Live load.

Distributed load .34 ton per foot run on 10 feet width

Impact 36 per cent.

$$\text{Bending moment} = \frac{.34 \times 2240 \times 5.5 \times 1.36 \times 32 \times 32 \times 12}{10 \times 8}$$

$$= 875,000 \text{ inch pounds.}$$

9 (j)

Knife edge load 6 tons at centre

$$\text{bending moment} = \frac{6 \times 2240 \times 5.5 \times 1.36 \times 32 \times 12}{10 \times 4}$$

$$= 960,000 \text{ inch pounds.}$$

Total bending moment = 3445000 inch pounds.

Now economical depth of a T-Beam

$$d = \sqrt{\frac{rM}{f_s b^1} + \frac{t}{2}}$$

Where r = ratio of cost of steel to cost of concrete per unit volume in place

t = depth of slab

b^1 = thickness of stem or web of T-Beam

and d = depth of T-Beam

Cost of steel = Rupees 16 per hundredweight

$$= \frac{16 \times 484}{112} = \text{Rs. 69 per cubic foot}$$

Cost of concrete = Rupee one per cubic foot

Therefore $r = 69$ say 70

$$\text{Therefore } d = \sqrt{\frac{70 \times 3445000}{18000 \times 14} + \frac{t}{2}}$$

$$= \sqrt{955} + 3.5$$

$$= 31 + 3.5 = 34.5$$

make stem 28 inches so that the total depth = 35 inches

Assume cover = $3\frac{1}{2}$ inches

Effective depth = $31\frac{1}{2}$ inches

Breadth of flange of T-Beam, $b = 5$ feet 6 inches = 66 inches because
(i) this does not exceed one third of the effective span of the T-beam viz. 32/3 feet (ii) the breadth of the stem plus 12 times the thickness of the slab i.e. $14 + 12 \times 7 = 98$ inches.

$$\text{Tensile steel, } A_s = \frac{M}{jd f_s} = \frac{3445000}{18000 \times .9 \times 31.25} = 6.66 \text{ square inches.}$$

Use 3 bars $1\frac{1}{4}$ inches diameter at bottom = 3.681 square inches.

Use 3 bars $1\frac{1}{4}$ inches diameter at top = 2.982 square inches

Total = 6.663 square inches.

From graphs on page 57 of "Reinforced Concrete Bridge Design" by Chetty and Adams

$$k = 26$$

$$j = .92$$

10 (j)

Test for shear. The amount of total shear at points 0, 5, 10 and 15 feet away from support, i.e., 1, 6, 11, 16 feet from the centre of the bearing of the beam has been worked out below, considering the beam fully loaded with live load between each point and the far support, as this gives the maximum shear.

Distance from centre of bearing $x =$	1	6	11	16
Dead load shear $1050 (16 - x) =$	15750	10500	5250	0
Live load uniformly distributed at .34 ton per foot run for one traffic lane $570 \times \frac{(1-x)^2}{2L} = 8.9 (32 - x) =$	8550	6000	3560	2000
Knife edge load of 9 tons for one traffic lane $W \times \frac{1-x}{L} = \frac{9 \times 2240 \times 5.5 \times 1.36}{10} \times \frac{1-x}{32} = 471 (1-x) =$	14600	12200	10000	7500
Total shear	38900	28700	18810	9500
$v = \frac{V}{14 \times .92 \times 32}$	95	65	45	26

Use $\frac{1}{2}$ inch diameter two legged stirrups for taking the above shear spacing of stirrups =

$$S_1 = \frac{2 \times .196 \times 18000 \times .92 \times 32}{38900} = 5.5 \text{ inches}$$

$$S_6 = \frac{2 \times .196 \times 18000 \times .92 \times 32}{28700} = 7.3 \text{ inches}$$

$$S_{11} = \frac{2 \times .196 \times 18000 \times .92 \times 32}{18810} = 10 \text{ inches}$$

$$S_{15} = \frac{2 \times .196 \times 18000 \times .92 \times 32}{9500} = 19 \text{ inches.}$$

For the sake of convenience use stirrups 6 inches apart upto $7\frac{1}{2}$ feet from support, 9 inches apart upto 12 feet and 12 inches apart beyond it upto the centre.

Table VI gives sizes of T-Beams and reinforcement for 20, 25, 30, 35 and 40 feet spans. Beams for other spans between these figures can be easily interpolated. Figure 5 shows a cross section and longitudinal section for a 30 feet span T-Beam.

11. *Costs.*—Costs of superstructure of various spans have been worked out in Table VII for simple slabs, Rolled Steel Beams and T-Beams assuming the following rates for average conditions :—

Rolled Steel Beams placed in position Rs. 15/- a hundredweight.

Reinforced Cement Concrete in slabs including reinforcement and formwork Rs. 2/- a cubic foot.

Reinforced cement concrete in T-Beams (Stem only) including reinforcement and formwork Rs. 3/8/- a cubic foot.

From this table it will be apparent that T-Beams are in every case cheaper than Rolled Steel Beams. Upto 15 feet span, it is most convenient to use simple slabs, though a T-Beam bridge for 15 feet span is a little bit cheaper than a simple slab. Where however it is difficult to construct T-Beams due to very high cost of stone and coarse sand, and difficulty of formwork and adequate supervision, Rolled Steel Beams offer a convenient method of construction.

12. *Substructures.*—Only the design of superstructures has been dealt with so far. Substructures however form as important a part of bridges as superstructures, but it is not feasible to standardise their designs due to great variations in nature of subsoil, materials of construction, and heights above bed level. The term 'substructures' is taken to include abutments, piers, wingwalls and their foundations which may be either simply shallow or consist of wells of masonry or concrete, or steel or concrete piles. Design of such structures is dealt with in detail in various standard books on Bridges. I have confined myself in this paper to masonry abutments, wingwalls and piers with open foundations in average soil conditions, because short span bridges are generally built under such simple conditions.

Masonry abutments and wingwalls are designed on the well-known Rankine Theory of Retaining walls. The "Indian Railway Standard Code of Practice for the Design of Bridge Piers and Abutments" adopted in 1936, recommends the following *data* to be assumed for the design of these structures.

"Para III b (2)

Earth pressure on abutments, and return and wing walls:—The horizontal pressure due to the weight of the earth and surcharge of the train load acting on the back of an abutment shall be calculated as follows

Let ϕ = angle of repose of the fill

h = vertical height of wall in feet.

h' = height of surcharge in feet

= 5 feet for abutments and return walls in box type of abutments. In the case of splayed wing walls the only surcharge to be taken is that due to the earth slope.

P = horizontal earth pressure on a vertical section per lineal foot of wall.

w = weight of filling per cubic foot.

y = height of " P " above the base.

$$\text{Then } P = \frac{1}{2} wh(h + 2h') \frac{1 - \sin \phi}{1 + \sin \phi}$$

$$y = \frac{h^2 + 3hh'}{3(h + 2h')}$$

Abutments and wing walls shall be designed by taking the angle of repose ϕ in the above formula as 45 degrees provided that a note shall be added to the plans to the effect that dry stone or brickbats backing with a puddle base and efficient drainage shall be provided. In banks of black cotton soil a section of bank of good material should be put in between the packing and the black cotton soil. In other cases where the intention is to use sand or other similar material for the back fill which is not likely to get consolidated, the angle of repose adopted shall be that appropriate for such material.

Para III b (3) Wind and water pressure.—Water pressure shall be considered in the design of the masonry of piers which are liable to be immersed for at least 20 feet above normal bed level. Wind pressure shall be taken into account for bridges of spans of 60 feet and over.

Para V. Working Stresses.—The maximum permissible compressive stress on unreinforced masonry shall not exceed one eighth of the crushing strength of the material employed. The tensile stress in masonry may be permitted upto one-fortieth of the ultimate crushing strength of the material. Sound brickwork in lime which has hardened may in the absence of tests be assumed to have a crushing strength of not less than 40 tons per square foot. Brickwork in cement mortar may in the absence of tests be assumed to have a crushing strength of not less than 64 tons per square foot.

Para VII. Foundation Pressure.—For standard designs the maximum intensity of pressure on the soil shall not exceed 2 tons per square foot for shallow foundations in good soils of a depth of not less than 4 feet. In deltaic areas such as Bengal the pressure shall not exceed 1 ton per square foot. For greater depths, foundation pressures may be increased by 1 hundredweight per square foot per foot of depth. In important cases and in cases of doubt suitable test of the bearing capacity of soil shall be made and the size of foundation footings or slabs modified accordingly.

Para VIII. Combined maximum stresses on Foundation Pressures.—The sum of the stresses caused by dead load, live load and longitudinal forces (i.e., earth pressure and braking effort or tractive force) shall not exceed the limits specified in sections v and vii. The sum of the above stresses together with wind and water pressure and where necessary Seismic forces shall not exceed the above permissible stress by more than 25 per cent.

Para IX. Wing Walls.—Abutments designed with splay wing walls shall have a vertical division from top to bottom near the junction of the wing walls to the abutments so as to permit of unequal settlement due to the greater intensity of pressure on the abutment foundation."

The above assumptions adopted for Bridges on Indian Railway appear to be quite suitable and reasonable for adoption for bridges on Indian Roads. h' or the height of surcharge in feet however requires to be decided for Indian Standard Loading. The distributed load is .34 ton per foot run for ten feet width, and is therefore equivalent to $\frac{.34 \times 2240}{10}$ pounds or 76 pounds per square foot. Assuming the knife edge load of 6 tons spread over the length of the loaded

ack-fill say on an average about 10 feet, this will reduce to $\frac{6 \times 2240}{10 \times 10}$ pounds or 135 pounds. Adding the two, the total is 211 pounds, assuming 25 per cent impact this adds up to 264 pounds and is equivalent to about 2.5 feet height of earth. Considering that the height of surcharge for railway train loads which are much heavier than the heaviest road load is only assumed as five feet, two feet six inches appears quite a reasonable assumption. Designs of abutments and piers for Indian conditions have been dealt with in detail in Volume III of the Military Engineer Services Hand Book, and "Notes on the Design of Culverts and Bridges" by Mr. M. G. Banerjee, assuming very nearly the data recommended above, and standard types for these have been recommended in plates XVII and XVIII on pages 186 and 187 (1925 Edition) of the former and on page 118 of the latter. These types show abutments with vertical as well as battered fronts. The author prefers the construction of abutments with a vertical front instead of a battered front, as the latter requires stepped construction which looks unsightly on the front face open to view. A type design for an abutment based on the above assumptions is shown in Figure 6 of this paper. The widths of abutment at top have been proposed in multiples of $4\frac{1}{2}$ inches—the width of a brick. To show that the type design proposed is safe, a detailed design for an abutment of a T-Beam bridge 30 feet span with a height of 20 feet above bed level upto bottom of beams has been worked out below:—

13. Calculations for abutment (See Figure 7). The abutment will be of brick masonry in cement mortar (1 cement 6 sand) above bed level, and (1 cement 3 sand) below bed level. Weight of masonry is taken at 125 pounds per cubic foot. Weight of earth back fill is taken at 100 pounds per cubic foot, (*vide* page 6, Indian Roads Congress Standard Bridge Specification).

Depth of T-Beam with slab = 35 inches.

Depth of wearing coat = 3 inches.

Total = 38 inches.

or 3 feet 2 inches.

Therefore, total height above bed level to road surface is 23 feet 2 inches. Make depth below bed level 6 feet. Therefore total height above bed of foundation is 29 feet 2 inches. Depth below bed level being 6 feet is about $\frac{1}{5}$ th of total height H. Make toe projection 3 feet, and width at base of foundation 12 feet from face of abutment, making total width of base of foundation 15 feet.

Assume surcharge load = 2.5 feet of earth filling.

Loads on the abutment.

(a) Dead load due to one beam per foot run.

Wearing coat = $\frac{3}{12} \times \frac{11}{12} \times 140 = 193$ pounds

Slab = $\frac{7}{12} \times \frac{11}{12} \times 144 = 462$ pounds

Stem of Beam = $\frac{28 \times 14}{144} \times 144 = 392$ pounds

Total = 1047 pounds.

Total length of Beam = 34 feet.

14 (j)

Therefore load on one abutment due to one beam on a width of $5\frac{1}{2}$ feet = 1047×17 pounds = 17799 pounds

Therefore load per foot width = $\frac{17799}{5\frac{1}{2}} =$ 3240 pounds

(b) Live load distributed per foot width

$$= \frac{.34 \times 34 \times 2240}{2 \times 10} = 1295 \text{ pounds}$$

add impact 36 per cent = 470 pounds

Total = 1765 pounds

Knife edge load including impact

$$= \frac{9 \times 1.36 \times 2240}{10} =$$

2740 pounds

Total = 7745 pounds

Say, 7800 pounds = w_1

Weight of back fill

$$\frac{175}{6} \times \frac{1}{2} \times 8\frac{1}{2} \times 100 = 12600 \text{ pounds} = w_2$$

Weight due to surcharge.

$$8\frac{1}{2} \times \frac{5}{2} \times 100 = 2150 \text{ pounds} = w_3$$

Weight of masonry and concrete

(a) Triangular portion

$$\frac{1}{2} \times 8\frac{1}{2} \times \frac{175}{6} \times 125 = 15750 \text{ pounds} = w_4$$

(b) Rectangular portion

$$3\frac{3}{8} \times \frac{175}{6} \times 125 = 12300 \text{ pounds} = w_5$$

Total vertical weight is therefore = 50600 pounds per foot length of the abutment = F.

The horizontal distances from the vertical face of the abutment of each of the above vertical forces are as below, ignoring the toe projection

$W_1 =$ 7800 pounds at 1 foot

$W_2 =$ 12600 pounds at $3\frac{3}{8} + 8\frac{1}{2} \times \frac{1}{2} = 9\frac{1}{8}$ feet

$W_3 =$ 2150 pounds at $3\frac{3}{8} + 8\frac{1}{2} \times \frac{1}{2} = 7\frac{11}{16}$ feet

$W_4 =$ 15750 pounds at $3\frac{3}{8} + 8\frac{1}{2} \times \frac{1}{2} = 6\frac{1}{2}$ feet

$W_5 =$ 12300 pounds at $3\frac{3}{8} \times \frac{1}{2} = 1\frac{11}{16}$ feet

The moment of F about the face of the abutment = the sum of the moments of its components,

Therefore, the distance of F from the vertical face

$$= \frac{7800 \times 1 + 12600 \times 9\frac{1}{8} + 2150 \times 7\frac{11}{16} + 15750 \times 6\frac{1}{2} + 12300 \times 1\frac{11}{16}}{50600}$$

= 5.2 feet,

By Rankine's formula

The horizontal earth pressure for a surcharged wall

$$P = \frac{1}{2} \times wh(h + 2h') \frac{1 - \sin \phi}{1 + \sin \phi}$$

where w = weight of one cubic foot of earth = 100 pounds.

$$= \frac{1}{2} \times 100 \times 29\frac{1}{2} \times (29\frac{1}{2} + 2 \times 2\frac{1}{2}) \frac{1 - \sin 45^\circ}{1 + \sin 45^\circ}$$

$$= 8300 \text{ pounds}$$

Its point of application will be at a height from base according to Rankine's formula

$$= \frac{h^2 + 3hh'}{3(h + 2h')} = \frac{(29\frac{1}{2})^2 + 3 \times 29\frac{1}{2} \times \frac{5}{2}}{3(29\frac{1}{2} + 5)}$$

$$= 10.4 \text{ feet}$$

The resultant of the two forces will pass through a point in the base $\frac{8300 \times 10.4}{50600}$ i.e., 1.7 feet from line of action of the vertical force F towards the vertical face of the abutment, which is $5.2 - 1.7$, i.e., 3.5 feet from the vertical face or 6.5 feet from the toe. This point is within the middle third of the base and its eccentricity from the centre is only 1 foot ($7.5 - 6.5$). The above result is also shown graphically in figure 7 where

$$mn = F = 50600 \text{ pounds and } nq = P = 8300 \text{ pounds}$$

$R = 51300$ pounds and intersects the base 1 foot beyond the centre i.e., within the middle third and thus satisfies the condition of stability against over-turning.

The stability of the abutment should also be investigated with no live load on the bridge and no surcharge on the fill over the back of the wall but with the assumption that the train of vehicles has just reached the point just where the fill over the wall ends; in this case the weights are as below :—

$$W_1 = 3240 \text{ pounds at 1 foot}$$

$$W_2 = 12600 \text{ pounds at } 9\frac{1}{2} \text{ feet}$$

$$W_3 = \text{Nil}$$

$$W_4 = 15750 \text{ pounds at } 6\frac{1}{2} \text{ feet}$$

$$W_5 = 12300 \text{ pounds at } 1\frac{11}{16} \text{ feet}$$

$$\text{Total } F = 43890 \text{ pounds acting at}$$

$$\frac{3240 \times 1 + 12600 \times 9\frac{1}{2} + 15750 \times 6\frac{1}{2} + 12300 \times 1\frac{11}{16}}{43890}$$

$$= 5.5 \text{ feet}$$

Horizontal earth pressure and its line of action remain the same.

The resultant R in this case will pass through $\frac{8300 \times 10.4}{43890}$ i.e., 2 feet away from the line of action of the vertical forces or 1 foot from the centre of the base which is the same point through which the previous resultant R intersects the base. The abutment is therefore safe under this condition too.

Pressure on foundation, (Vide Military Works Hand Book Volume III page 23).

The average pressure on the foundation

$$P_a = \frac{F}{B + T} = \frac{50600}{15} = 3370 \text{ pounds per square foot.}$$

P_o = The difference in pressure at the toe and heel due to eccentricity of the resultant R

$$P_o = \frac{6 \times F \times e}{(B + T)^2} = \frac{6 \times 50600 \times 1}{15 \times 15} = 1350 \text{ pounds.}$$

Maximum pressure at toe = $3370 + 1350 = 4720$ pounds per square foot.

Permissible pressure is 2 tons and 2 hundredweights i.e., 4704 pounds because the foundation is 6 feet below bed level. Therefore this is just safe.

Maximum pressure at heel = $3370 - 1350$
= 2020 pounds per square foot. (safe)

Stability against sliding.

For masonry on earth the co-efficient of friction is .40.

Therefore the frictional resistance of the wall against sliding

$$= 50600 \times .4 = 20240 \text{ pounds}$$

$$\text{Sliding force} = 8300 \text{ pounds}$$

$$\text{Factor of safety} = \frac{20240}{8300} = 2.44$$

which is quite sufficient.

As the resultant lies within the middle third of the base, and the maximum pressure on the foundation and the resistance to sliding are satisfactory the design is suitable.

The design should however also be tested for its stability along bed level A, (vide Figure 8).

$$\text{Horizontal Earth pressure } P = \frac{1}{2} \times 100 \times 23\frac{1}{2} \times (23\frac{1}{2} + 5) \times .17 = 5474 \text{ pounds.}$$

$$\text{This acts at a point } \frac{23\frac{1}{2} \times 23\frac{1}{2} + 3 \times 23\frac{1}{2} \times \frac{1}{2}}{3(23 + 5)} = 8.3 \text{ feet above the bed level.}$$

The vertical forces are as below :—

$$W_1 = 7800 \text{ pounds at 1 foot.}$$

$$W_2 = \text{back fill} = \frac{1}{2} \times 7 \times 23\frac{1}{2} \times 100 = 8050 \text{ pounds, acting at } 3\frac{3}{8} + 7 \times \frac{2}{3} \text{ i.e. at } 8\frac{1}{2} \text{ feet.}$$

$$W_3 = \text{weight due to surcharge} \\ = 7 \times \frac{5}{8} \times 100 = 1750 \text{ pounds acting at } 6\frac{1}{2} \text{ feet.}$$

$$W_4 = \text{weight of masonry triangular portion.} \\ = \frac{1}{2} \times 7 \times 23\frac{1}{2} \times 125 = 10060 \text{ pounds acting at } 3\frac{3}{8} + 7 \times \frac{1}{3} \text{ i.e. at } 5\frac{1}{2} \text{ feet.}$$

17 (j)

W_r = weight of rectangular portion of masonry
 $= 3\frac{3}{8} \times 23\frac{1}{8} \times 125 = 9850$ pounds acting at $1\frac{1}{8}$ feet.

Therefore the distance of the total vertical force F from the vertical face
 $= \frac{7800 \times 1 + 8050 \times 8\frac{3}{4} + 1750 \times 6\frac{7}{8} + 10060 \times 5\frac{1}{4} + 9850 \times 1\frac{1}{8}}{37510}$
 $= 4.3$ feet.

The resultant R of P and F will pass through $\frac{547\frac{1}{2} \times 8.3}{37510}$ feet, i.e., 1.2 feet away from the line of action of the vertical forces i.e., $4.3 - 1.2 = 3.1$ feet from the vertical face. As the width of base is $10\frac{1}{2}$ feet at bed level, and the resultant intersects it at very nearly, its one third and well within its middle half, this is safe against overturning.

Pressure at bed level.

Average pressure.

$$P_a = \frac{37510}{10.3} = 3640 \text{ pounds}$$

eccentricity = 2

$$P_c = \frac{6 \times 37510 \times 2}{10.3 \times 10.3} = 4246 \text{ pounds.}$$

Therefore maximum pressure at toe $= \frac{3640}{2} + \frac{4246}{2} = 7886$ pounds
 $= 3.5$ tons which is safe.

The design of the abutment is therefore safe considered from every point of view. The type design recommended will therefore suit for all spans and depths.

For piers and wing walls, the typical designs shown on pages 186 and 187 of Military Engineer Services Hand Book Sixth Edition 1925, Volume III (Roads), referred to earlier, are very suitable, and should be adopted.

14. Acknowledgment is due to the following excellent publications on the subject which have been consulted in the compilation of this paper:—

1. "Standard Specification and Codes of Practice for Road Bridges in India" published by the Indian Roads Congress.
2. "Reinforced Concrete Bridge Design" by Messrs. C. S. Chetty and H. C. Adams.
3. Military Engineer Services Handbook Volume III (Roads) Sixth Edition 1925.
4. "Notes on the Design of Culverts and Bridges" by Mr. M. G. Banerjee.
5. "Indian Railway Standard Code of Practice for the Design of Bridge Piers and Abutments" adopted 1936.
6. "Handbook on the Code of Practice for Reinforced Concrete by Messrs. W. L. Scott and W. H. Glanville.
7. Reinforced Concrete Bridges by Mr. W. L. Scott.
8. Reinforced Concrete Construction by Mr. G. A. Hool.

TABLE I.

Table showing impact factor for spans upto 500 feet for 2 lanes of traffic vide para 5.

Span	Impact factor per cent.	Span	Impact factor per cent.
2	68	30	36
4	64	32	35
6	60	34	34
8	57	36	33
10	54	38	32
12	52	40	31
14	50	50	27
16	47	75	21
18	45	100	17
20	43	150	12
22	42	200	9.4
24	40	300	6.6
26	39	400	5
28	37	500	4.1

Note—Maximum permissible impact factor is 50 per cent.

TABLE II.

Resistance Moments of Reinforced Concrete Slabs.

Stress in concrete $f_c = 750$ pounds per square inch.
 Stress in steel $f_s = 18000$ " " " "
 Co-efficient $R = 137$
 Percentage of steel $p = .0089$
 Moment of Resistance $= Rbd^2$ where
 effective depth $d =$ total depth, t minus $1\frac{1}{2}$ inches
 breadth $b =$ twelve inches
 Area of steel $A_s = pbd$

Slab thick- ness in inches.	Effective depth in inches.	Moment of Resistance in inch pounds M_n	Steel requir- ed in square inches A_s	Main Steel Bars proposed.	A_s Supplied	Distribution steel Bars proposed.	Weight of slab per square foot in pounds
1	2	3	4	5	6	7	8
7	$5\frac{1}{2}$	49400	0.59	$\frac{3}{8}$ in. diameter at 6 in. centres	0.60	$\frac{3}{8}$ in. diameter at $10\frac{1}{2}$ in. centres	84
$7\frac{1}{2}$	6	59200	0.64	$\frac{3}{8}$ in. diameter at $5\frac{1}{2}$ in. centres	0.67	$\frac{3}{8}$ in. diameter at $9\frac{1}{2}$ in. centres	90
8	$6\frac{1}{2}$	69500	0.7	$\frac{3}{8}$ in. diameter at 5 in. centres	0.74	$\frac{3}{8}$ in. diameter at 9 in. centres	96
$8\frac{1}{2}$	7	80600	0.75	$\frac{3}{8}$ in. diameter at 5 in. centres	0.74	$\frac{3}{8}$ in. diameter at 9 in. centres	102
9	$7\frac{1}{2}$	92500	0.8	$\frac{3}{8}$ in. diameter at $4\frac{1}{2}$ in. centres	0.82	$\frac{3}{8}$ in. diameter at 8 in. centres	108
$9\frac{1}{2}$	8	105300	0.86	$\frac{3}{8}$ in. diameter at 4 in. centres	0.92	$\frac{3}{8}$ in. diameter at 7 in. centres	114
10	$8\frac{1}{2}$	118000	0.91	$\frac{3}{8}$ in. diameter at 4 in. centres	0.92	$\frac{3}{8}$ in. diameter at 7 in. centres	120
$10\frac{1}{2}$	9	133000	0.96	$\frac{3}{8}$ in. diameter at $5\frac{1}{2}$ in. centres	0.96	$\frac{3}{8}$ in. diameter at 12 in. centres	126
11	$9\frac{1}{2}$	146000	1.01	$\frac{3}{8}$ in. diameter at 5 in. centres	1.06	$\frac{3}{8}$ in. diameter at 11 in. centres	132
$11\frac{1}{2}$	10	164400	1.07	$\frac{3}{8}$ in. diameter at 5 in. centres	1.06	$\frac{3}{8}$ in. diameter at 11 in. centres	138
12	$10\frac{1}{2}$	181000	1.12	$\frac{3}{8}$ in. diameter at $4\frac{1}{2}$ in. centres	1.18	$\frac{3}{8}$ in. diameter at 10 in. centres	144
$12\frac{1}{2}$	11	199000	1.17	$\frac{3}{8}$ in. diameter at $4\frac{1}{2}$ in. centres	1.18	$\frac{3}{8}$ in. diameter at 10 in. centres	150
13	$11\frac{1}{2}$	216000	1.22	$\frac{3}{8}$ in. diameter at 4 in. centres	1.32	$\frac{3}{8}$ in. diameter at $8\frac{1}{2}$ in. centres	156
$13\frac{1}{2}$	12	237000	1.28	$\frac{3}{8}$ in. diameter at 4 in. centres	1.32	$\frac{3}{8}$ in. diameter at $8\frac{1}{2}$ in. centres	162
14	$12\frac{1}{2}$	256000	1.33	$\frac{3}{8}$ in. diameter at 4 in. centres	1.32	$\frac{3}{8}$ in. diameter at $8\frac{1}{2}$ in. centres	168
$14\frac{1}{2}$	13	278000	1.39	$\frac{3}{8}$ in. diameter at 5 in. centres	1.44	$\frac{3}{8}$ in. diameter at 8 in. centres	174
15	$13\frac{1}{2}$	298000	1.44	$\frac{3}{8}$ in. diameter at 5 in. centres	1.44	$\frac{3}{8}$ in. diameter at 8 in. centres	180

TABLE III.

Design of simply supported slabs for spans 4 feet to 18 feet for Indian Roads Congress Standard Loading and wearing coat of three inches thick cement concrete.

Span in feet	Assume thickness of slab in inches.	Effective span in feet.	Dead load bending moment in inch pounds.	Live load bending moment including impact in inch pounds.	Total bending moment in inch pounds.	Shear due to dead load.	Shear due to distributed live load including impact.	Shear due to knife edge load including impact.	Total shear.	Shear in lbs. per square inch.	Bond stress in lbs. per square inch.
4	7	4.5	3620	42600	46220	270	258	3024	3552	63	192
5	7½	5.5	5700	53150	58850	352	319	3024	3625	60	168
6	8½	6.6	8900	64000	72900	460	380	3024	3864	53	135
7	9	7.6	12500	73406	85906	515	438	3024	4007	52	118
8	9½	8.7	17000	83000	100000	672	400	3024	1126	51	104
9	10	9.7	22800	92400	115200	783	555	3024	4362	50	102
10	10½	10.75	28200	100000	130000	867	615	3024	4506	49	113
11	11	11.8	36400	113100	149500	1027	678	3024	4729	48	101
12	11½	12.9	45000	123400	168400	1157	740	3024	4921	48	101
13	12	13.9	57000	133300	190300	1300	795	3024	5119	47	90
14	13	15	66000	142700	208700	1430	850	3024	5374	45	76
15	13½	16	78500	152100	230600	1630	910	3024	5564	45	76
16	14	17	90000	160000	250000	1750	950	3024	5724	45	76
17	14½	18.1	110000	167600	277600	1890	1010	3024	5924	44	80
18	15	19.1	117000	174500	291500	2060	1060	3024	6144	44	80

TABLE IV.

Bending moments for live load for continuous and semi-continuous slabs spans 5 feet to 20 feet for one foot width for Indian Standard loading.

Span.	*Bending moment for continuous span $\frac{wl}{12}$ in inch pounds without impact.	Impact factor per cent.	Total Bending moment including impact in inch pound.	Bending moment for end spans $\frac{wl}{10}$ in inch pound including impact.	Average live load per square foot including impact.
5	21055	50	31582	37899	1260
6	25266	50	37899	45478	1050
7	29477	50	44215	53059	905
8	33688	50	50532	60638	790
9	37899	50	56848	68218	700
10	42110	50	63165	75798	630
11	46321	50	69481	83377	570
12	50532	50	75798	90957	525
13	54743	50	82114	98538	485
14	58954	50	88431	106117	450
15	63165	50	94747	113697	420
16	67376	47	99033	118839	386
17	71787	47	105528	126633	364
18	75998	45	110197	132236	340
19	80209	45	116303	139564	320
20	84420	43	120721	144865	300

*Bending moment due to distributed load

$$= \frac{6.8 \times 2240}{10} \times \frac{L \times 12}{12} = 1523L$$

Bending moment due to Knife edge load

$$= \frac{6 \times 2240 \times L \times 12}{10 \times 6} = 2688L$$

$$\text{Total} = 4211L$$

TABLE V.

Design of Rolled Steel Beams placed 5 feet 6 inches apart and carrying a R. C. slab 7 inches thick and a wearing coat of cement concrete 3 inches thick.

Serial No.	Span.	Effective span.	Dead load Bending moment in inch.-tons.	Live Load Bending moment including allowance for impact in inch.-tons.	Total Bending moment in inch.-tons. M	Section modulus required about $xx = \frac{M}{s}$	Size of Suitable Beam in inches from Hand Book of Dorman Long & Co., Ltd. 1924 edition.	Weight per foot run.	Section Modulus.
1	10	11	56	229	285	35.6	12 x 5	30 lbs.	34.49
2	11	12	68	282	350	43.8	13 x 5	35 lbs.	43.62
3	12	13	78	302	380	47.5	14 x 5½	40 lbs.	53.87
4	13	14	92	325	417	52	14 x 5½	40 lbs.	53.87
5	14	15	106	348	454	57	15 x 6	45 lbs.	65.59
6	15	16	120	371	491	61	15 x 6	45 lbs.	65.59
7	16	17	137	371	508	63	15 x 6	45 lbs.	65.59
8	17	18	154	396	550	69	16 x 6	50 lbs.	77.26
9	18	19	172	400	566	71	16 x 6	50 lbs.	77.26
10	19	20	191	410	594	74	16 x 6	50 lbs.	77.26
11	20	21	210	488	698	87	18 x 6	55 lbs.	93.5
12	22	23.5	272	560	832	104	20 x 6½	65 lbs.	122.6
13	25	27	345	660	1005	126	20 x 6½	65 lbs.	122.6
14	27	29	410	715	1125	141	22 x 7	75 lbs.	152.4
15	30	32	500	810	1310	164	24 x 7½	90 lbs.	203.7
16	32	34	580	890	1470	184	24 x 7½	90 lbs.	203.6
17	35	37	682	1000	1682	210	21½ x 10 Compound Girder	109 lbs.	215.8
18	37	39	780	1070	1850	231	21½ x 10 Compound Girder	118 lbs.	257.4
19	40	42	924	1180	2104	263	21½ x 10 Compound Girder	127 lbs.	259.0

TABLE VI.

Design of T. Beams placed 5 feet 6 inches centre to centre carrying a 7 inches thick Reinforced concrete slab and a wearing coat of 3 inches thick cement concrete safe for Indian Standard Loading.

Span.	Total Bending moment in inch pound.	Depth of stem.	Width of stem.	Main Reinforcement.		Two legged Stirrups $\frac{1}{2}$ inch diameter bars.			a = Distance from centre line of bottom layer of bars to bottom of beam.	b = Distance of centre of outer bar from edge.	c = Distance from centre line of bottom layer of bars to bottom of beam.	d = "Cover" i.e., Distance from centre between the two layers of bars to bottom.
				Top layer. Number of bars with diameter in inches.	Bottom layer. Number of bars with diameter in inches.	Spacing 6 inches.	Spacing 9 inches.	Spacing 12 inches.				
15	1144000	16	12	2 × 1 inch dia.	3 × 1 inch dia.	0 to 4 feet	4 to 6 feet	6 to 7½ feet.	4 inches	2 inches	2 inches	3 inches
20	1717000	20	12	3 × 1 "	3 × 1 "	0 to 5 "	5 to 8 "	8 to 10 "	4 "	2 "	2 "	3 "
25	2510000	25	12	3 × 1 "	3 × 1 "	0 to 6 "	6 to 10 "	10 to 12.5 feet.	3½ "	2½ "	2½ "	3 "
30	3445000	28	14	3 × 1 "	3 × 1½ "	0 to 8 "	8 to 12 "	12 to 15 feet.	4½ "	2½ "	2 "	3½ "
35	4490000	32	14	3 × 1½ "	3 × 1 "	0 to 9 "	9 to 14 "	14 to 17.5 feet.	4½ "	2½ "	2 "	3 "
40	5770000	34	16	3 × 1½ "	3 × 1½ "	0 to 10 "	10 to 16 "	6 to 20 feet.	5½ "	2½ "	2½ "	4 "

TABLE VII.

Comparative costs of Superstructure of bridges of spans from 10 feet to 40 feet.

Span in feet.	Cost of simply supported slab in rupees.	Cost of Beam Bridges in Rupees, Superstructure (Slab and Beams only).				
		Cost of slab.	Cost of four R. S. Beams.	Cost of four T- Beams.	Total Cost of R.S. Beam Bridge.	Total cost of T-Beam Bridge.
		Rs.	Rs.	Rs.	Rs.	Rs.
10	450	300	200	...	500	...
15	820	420	400	320	820	740
20	...	550	650	510	1200	1010
25	...	700	975	810	1675	1510
30	...	830	1600	1250	2430	2080
35	...	950	2200	1650	3150	2600
40	...	1100	3000	2300	4100	3400

DISCUSSIONS ON PAPER No. J.

Mr. Brijmohan Lal (Panjab) :—One of the objects of the Indian Roads Congress as laid down in its Memorandum of Association is to promote the use of standard specifications and to propose specifications. With this in view, three very valuable papers Nos. 26, 27 and 28 were presented at the second meeting of this Congress held at Bangalore in January 1938, dealing exhaustively with the standard loading and design of highway bridges in India with special reference to the design of cement concrete bridges. As a result of discussion of these papers at the session it was resolved that the Council be instructed to take all necessary action to enable them to recommend standard loading, allowance for impact, essential specifications, permissible stresses etc. to be adopted by the Congress for bridge designing. Eventually the Congress published 'Standard Specification and Codes of practice for Road Bridges in India' in 1937. I am not aware as to how far the various Provincial and State Governments have yet accepted these standard loadings and specifications, but it is expected that sooner or later the Indian Roads Congress standards will be adopted everywhere in India. In the paper that I now have the pleasure to introduce before you an attempt has been made to go a step further and propose standard designs of Reinforced Concrete Bridges of short spans upto 40 feet based on these Standard Specifications and thus to put the latter to practical application. The design of reinforced concrete structures is a long process requiring a lot of time, and while it is possible to individually design bridges of long span which are built only occasionally, it appears necessary to have type designs for bridges of short spans which are frequently required to be constructed, and for which it is not possible to find time for designing individually. Type designs have, therefore, been worked out in this paper for bridges up to 40 feet span. This paper is only in the form of spade work and has been written merely to invite the attention of the members of this Congress to the problem. I shall, therefore, be very grateful for your valuable criticisms and suggestions for improvements on the designs, and the various graphs and tables in the paper. It is intended to revise the designs in the light of today's discussion on the paper, and it is hoped that the Congress will then consider it fit to be published in the form of type designs for general reference. There are, however, certain points in the paper which I would like to bring to your special notice.

In accordance with para D 22. (c) of the specifications, the distribution reinforcement in slabs has been kept as 20 percent of the main tensile reinforcement. It is, however, brought to notice that the Ministry of Transport has suggested the distribution steel to be 40 percent of main reinforcement for 4 feet span rising to 60 percent for 10 feet span limiting to .5 square inch per foot. The distribution reinforcement proposed in the paper *vide* Table II is as low as .12 square inches per foot. The opinion of the members of the Congress will be appreciated on this point.

In table IV in calculating bending moment for continuous spans, I have assumed it as $\frac{WL}{12}$ for intermediate spans and $\frac{WL}{10}$ for end spans for the sake of simplicity. In case of long bridges with a number of continuous spans, it would certainly be worthwhile to compute bending moments and

shears from the theorem of Three Moments, as discussed by Hool in Vol. II of his Reinforced Concrete Construction.

In the latter part of the paper, an attempt has been made to standardise the design of abutment, piers and wing walls. Standardization in this respect is very difficult owing to the large number of varying factors involved. Special attention is invited in this connection to para VIII on page 12 (j), in which the foundation pressure has been assumed as 2 tons per square foot. This appears to be on the higher side and deserves consideration at this meeting.

In the end I must thank Mr. Jagdish Prasad, the Secretary of the Congress for the pains that he took in correcting the proof of the paper abounding with mathematical figures and formulae.

With these few words, I have great pleasure in introducing my paper to you for discussion.

Rai Bahadur S. N. Bhaduri (Chairman):—The Paper is now open to discussion.

Mr. Jagdish Prasad (Government of India):—We should be very thankful to Mr. Brijmohan Lal for the pains he has taken in showing the actual application of the Indian Roads Congress loading to the design of short span bridges. There are certain features of design which, however, call for comment.

In paragraph 2 on page 6 (j), the Author says that slabs less than 7 inches thick are not safe for shear and bond stresses. This is incorrect. If instead of using $\frac{5}{8}$ -inch bars at 6 inches centres, $\frac{3}{4}$ -inch bars are used at closer spacing, the strength in bond would be appreciably increased. For a clear span of 3 feet, a 6-inch slab will be found quite suitable. Its particulars will be:—

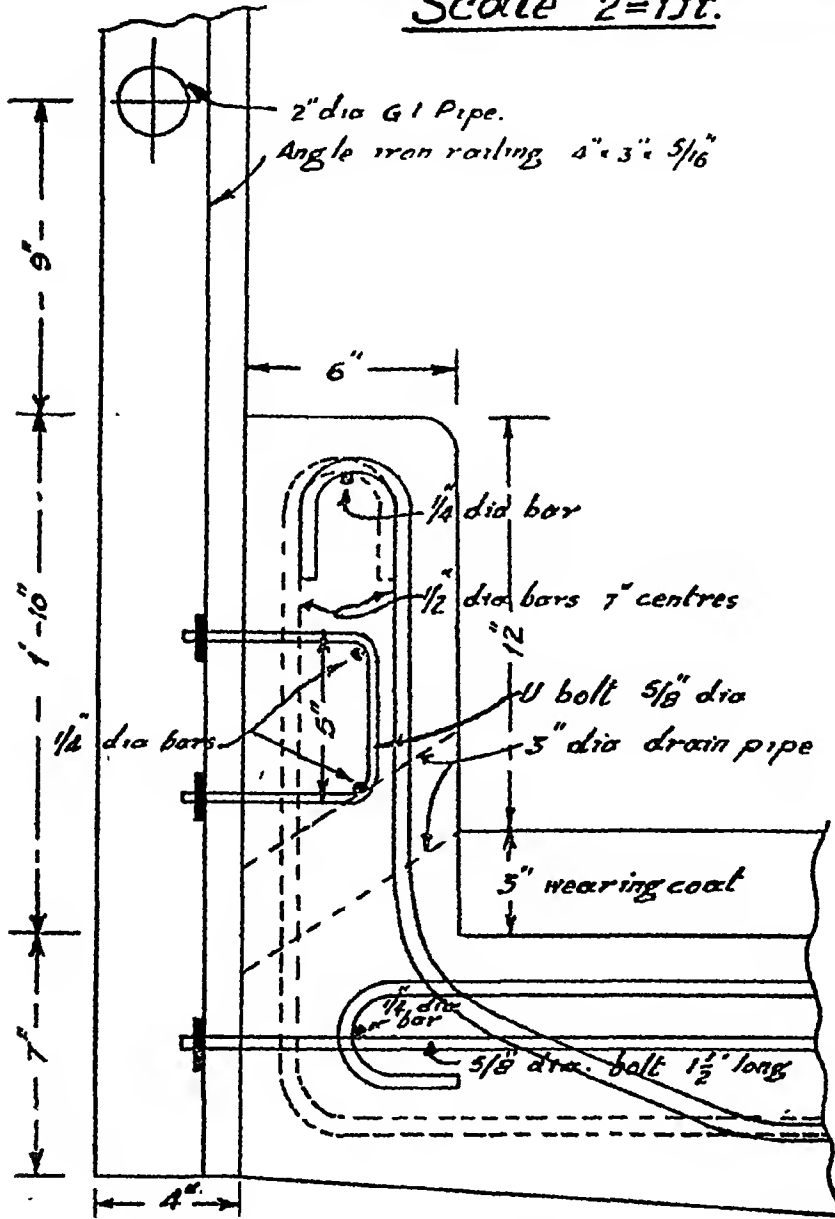
Depth to centre of steel	=	4.6 inches
Overall depth	=	6 inches
Reinforcement (main)	=	$\frac{3}{4}$ -inch diameter bars, 4 inches centres.
Reinforcement (distribution)	=	$\frac{1}{4}$ -inch diameter bars, 5 inches centres.

On page 7 (j), under "Design of Slab", the Author says, "Similarly the cantilever projection of 2 feet 6 inches will have the same maximum bending moment as a 5 feet slab, namely 31,582 inch-pounds". The calculations which follow will show that the Author's assumption is wrong. The maximum bending moment comes to 73,812 inch-pounds i.e., more than double of what the Author has assumed. The thickness of the slab at the cantilever support should be 8 inches and the area of steel 0.693 square inch per foot width. In order to avoid practical difficulties in increasing the thickness of the slab at the end supports, it is advisable to increase the spacing of R. S. Joists. It will be found that a spacing of 5 feet 10 inches will be suitable. Then, a slab 7 inches thick can be provided throughout. The cantilevers will be 1 foot 9 inches instead of 2 feet 6 inches long,

allowing the thickness of wheel kerbs as 6 inches which is ample. A more satisfactory method of fixing the railing posts to kerbs is shown below.

DETAIL OF KERB.

Scale 2"=1ft.



The Author has taken the safe working stress for steel joists as 8 tons per square inch, but it should be $7\frac{1}{2}$ tons per square inch, *vide* page 28 Indian Roads Congress Codes of Practice.

The Author has not given a full cross section of a T-beam bridge. While the spacing of T-beams at 5 feet 6 inches centre to centre may be satisfactory for spans upto 30 feet, it is not economical for spans beyond 32 feet. In large spans, it is more economical to use 3 ribs instead of 4 for a 20-feet roadway bridge.

On page 30 (j), figure 6, the bottom of foundation is shown as $\frac{H}{5}$ feet below bed level. This is likely to create misunderstanding because the depth of foundations depends on the depth at which soil suitable for foundations is met. The words "Bed Level" should be, therefore, deleted from the diagram. In all cases where foundations have to be taken down to a depth of $\frac{H}{5}$ feet or more, the abutments should be designed in accordance with figure 6, irrespective of the position of bed level. If it is not necessary to take the foundations down to $\frac{H}{5}$ feet below bed level, for example, in the case of a stream having a rocky bed, the toe projection may have to be reduced or dispensed with.

In the light of the above remarks I think, the word 'Make' in line 12 of para 13 (page 13, j) may be substituted by the word "Assume".

There are so many pitfalls in the design of bridges that it is very necessary to have type designs which the younger engineers, on whom falls the brunt of carrying out designs, may be able to refer to, and it is here that the Roads Congress can assist.

R. S. BEAMS WITH R. C. SLABS.

Design of cantilever slab.

Effective span $2\frac{1}{2}$ feet for dead load and $1\frac{3}{4}$ feet for live load.

(i) Bending moment due to distributed live load

$$= \frac{WL}{2} = \frac{0.68 \times 1\frac{3}{4} \times 2240}{2} = 1332 \text{ foot pounds.}$$

(ii) Bending moment due to concentrated live load at the end of cantilever

$$= WL = 0.6 \times 1\frac{3}{4} \times 2240 = 2350 \text{ foot pounds.}$$

(iii) Bending moment due to dead load of R. C. slab

$$= \frac{WL}{2} = (2\frac{1}{2} \times \frac{7}{17} \times 144) \frac{2.5}{2} = 262 \text{ foot pounds.}$$

(iv) Bending moment due to dead load of wearing coat

$$= \frac{WL}{2} = (1\frac{3}{4} \times \frac{3}{17} \times 140) \times 1\frac{3}{4} \times \frac{1}{2} = 54 \text{ foot pounds.}$$

(v) Bending moment due to dead load of parapet

$$= WL = (\frac{2}{17} \times \frac{1}{2} \times 144) \times 2\frac{1}{2} = 287 \text{ foot pounds.}$$

(vi) Bending moment due to railing weighing,
say, 10 pounds per running foot

$$= WL = 10 \times 2\frac{1}{2} = 25 \text{ foot pounds.}$$

Impact allowance 50 per cent on
live load, Bending moment

$$= 1841 \text{ foot pounds.}$$

Total Bending moment

$$= 6151 \text{ foot pounds.}$$

$$= 73812 \text{ inch pounds.}$$

Depth of slab to centre of steel

$$d = .0246 \sqrt{73812}$$

$$= 6.5 \text{ inches.}$$

Over-all depth of slab

$$= 6.5 + 1.5$$

$$= 8 \text{ inches.}$$

Area of steel required $A_s = p \times b \times d$

$$= .0089 \times 6.5 \times 12$$

$$= 0.693 \text{ square inch.}$$

Rai Sahib L. Fatehchand (United Provinces):— I congratulate the Author on the very great labour he has put in in bringing out this paper. I am only here to get information from the Author on certain points. These are:—

What height and what type of railing does the Author consider best suited to the bridges of this type?

What reinforcement does he consider to be necessary for reinforced brick railing and whether he would connect the reinforcement of the railing to that of the bridge at certain points?

What will be the weight of this railing?

What allowance has the Author made for this extra weight of the railings in his calculations for the reinforcement of the cantilever?

On page 7 (j), the Author says "the cantilever projection of 2 feet 6 inches will have the same maximum bending moment as a 5 feet slab". I think in designing the cantilever we shall also have to take into account the weight of the railing to be built on the cantilever, especially if this happens to be a masonry railing.

What thickness and what kind of wearing coat does the Author suggest to be given for bridges over *kutchra* and *pucca* roads respectively? Does he consider a cushion to be at all necessary between the slab and the wearing coat? What type of wheel guards does he recommend, i.e., of R. S. Joists, or of L or T-iron or of R. C., and to what depth will he take this below the road surface? Would he like to fill up the web of the R. S. beams carrying the roadway, with cement concrete, and if so, what percentage economy roughly will be made thereby in designing an R. S. Joist of comparatively smaller section than what would have been necessary in case the R. S. Joist had not been so treated with cement concrete?

Does he consider any arrangement for the expansion and contraction of R. S. beams and of the slabs to be necessary, and if so, over what spans?

What does the Author suggest to prevent bump at the junction of the *pucca* roadway of the bridge with the road on bank? Does he consider pitching to be necessary to prevent scour on the down-stream side in all cases?

Up to what depth of abutment foundations does he consider curtain walls to be necessary? What depth will he give to the masonry foundations of curtain and wing-walls on the down-stream side in cases where there is an excessive fall in levels, within a few hundred feet and when it is not possible to fix up the limit of the correct level due to continued slope for miles together?

These are some of the points on which I would seek the advice of the Author as much as he can find it possible to give in his reply. For the preparation of cement and sand mortar for work above bed level, I think a proportion of 1 to 5 to be more suited than 1 to 6 to make an allowance for the different kinds of streams, due to workmen, cuttings and the sliding of girders over it and, not unoften, the flooding of the river during the course of construction.

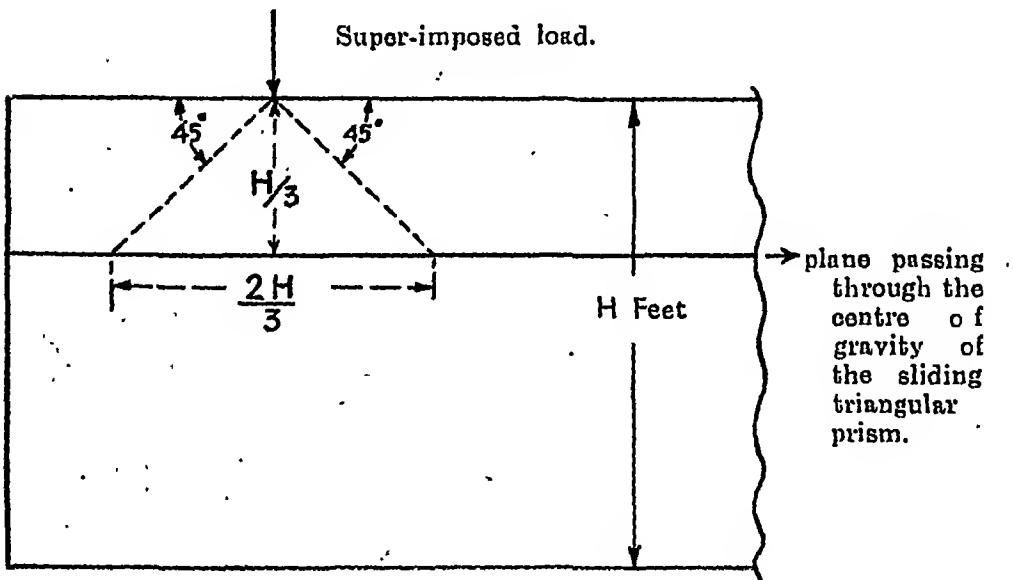
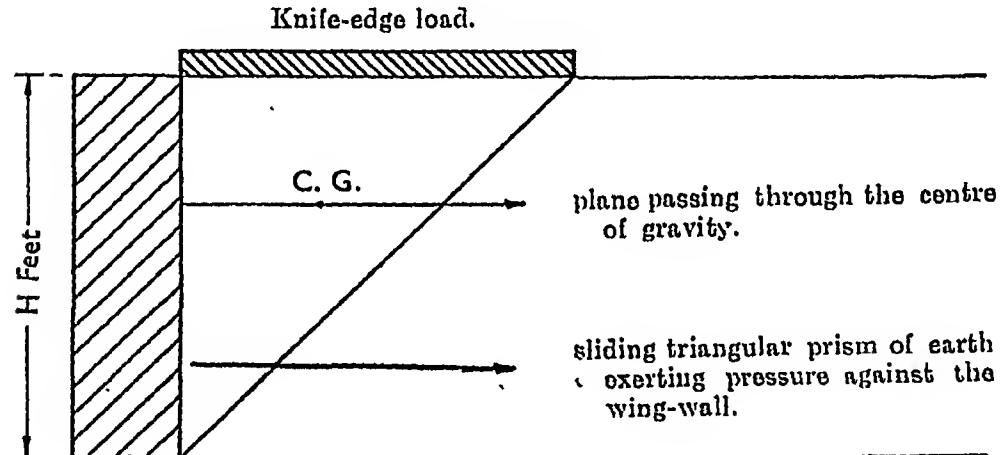
Mr. M. Mahapatra (Cuttack):—Figure 3 at page 27 (j) suggests the bending up of alternate main tensile reinforcements and provision of additional top reinforcements to take up the negative bending moment at supports. By this the strength of main tensile reinforcements is reduced to half and the bond stress is affected considerably. In an ordinary bridge, the R. C. Slabs are not built into masonry. Earth filling, soling and metalling form the loads on the ends. These slabs can not be considered as fixed. Further, when the filling and soling etc. are removed from the ends, the slab acts as a freely supported one. In such cases it seems desirable to continue the main tensile reinforcements upto the end, and to provide additional top reinforcements extending to a distance of $\frac{1}{5}$ of the span from the supports. These top reinforcements should be designed to be sufficient to withstand a negative bending moment equal to half of the maximum positive bending moment at the centre of the span.

Covering concrete for slabs has been kept as $1\frac{1}{2}$ inches. As the covering concrete does not give additional strength to reinforced structures, the minimum cover necessary, in my opinion, should not be more than one inch when the aggregates used are $\frac{1}{2}$ inch to $\frac{3}{4}$ inch size.

With regard to Page 12 (c) para IX of the paper, Wing-Walls, it will be observed that for computing earth pressure against wing-walls, the super-imposed knife-edge load of 6 tons has been assumed as distributed over an area of 10 feet \times 10 feet or 100 square feet, irrespective of the height of the wall. It is not clear how the load can affect such an area. The pressure exerted by backfill against a retaining wall is due to the sliding of a triangular prism of earth and is proportional to the height of the wall. As the filling beyond a point at a distance equal to the height of the wall produces no effect, the super-imposed load placed across the length of the

wall within a distance equal to the height should be taken into consideration. Taking the angle of dispersion as 45 degrees and the height of the wall as H feet, the knife-edge load will spread over a width of $\frac{2H}{3}$ feet along the length of the wall on the plane passing through the centre of gravity of the triangular prism. This gives an additional intensity of pressure of $\frac{\frac{w}{16} \times H}{H \times \frac{2H}{3}}$ tons, or $\frac{2016}{H}$ pounds per square foot and an equivalent height of surcharge of $\frac{2016}{wH}$ feet when w is the weight of a cubic foot of back-fill. This shows that the equivalent height of surcharge due to the knife-edge load varies as the height of the wingwall and is inversely proportional to it. I would request the Author for further discussion of the point.

SKETCH.



Mr. A. Nageswara Ayyar (Madras) :—I should like only to touch on one point. In the case of small slab bridges, the concentrated live load bears a very large proportion to the total load. The common assumption made in designing these slabs is that this concentrated load is distributed over a certain width on each side of the load. When the load comes to the end the slab is only on one side and the area of distribution will be virtually one-half of what it will be if the load is in the centre. Hence the thickness of the slab at the end will be considerably more than at the centre. This can be provided for either by increasing the reinforcement or what is better, to design the wheel-guard as an inverted beam to give the required stiffness at the end. This factor is very important and is often ignored in the design of slab culverts.

Mr. K. K. Nambiar (Mangalore) :—The Author has stated in his paper that to keep the bond-stress within safe limits, the minimum thickness of the R. C. Deck should be seven inches. This has already been remarked to be incorrect as by using larger number of rods of smaller diameter the bond-stress could be kept within safe limits. However, to resist the local effect of concentrated loads, it is generally considered safe not to reduce the thickness of the deck to less than seven inches.

Referring to page 9 (j) of the Paper, the Author has worked out the area of tensile steel required as

$$A_s = \frac{M}{jd f_s} = 6.66 \text{ square inches.}$$

Using 3 bars $1\frac{1}{4}$ inches diameter at bottom = 3.681 square inches
 and 3 bars $1\frac{1}{8}$ inches diameter at top = 2.982 square inches
 making a total of 6.663 square inches

But as there are two layers of rods employed, the value of f_s will be the average unit stress in the tension steel, d being the effective depth of the group of rods used. Therefore, the stress in the lower row of bars should be separately investigated to see that it does not exceed 18,000 pounds per square inch.

When one hind wheel of a steam roller is just brushing against the curb in the cantilever portion of the deck and the other wheel is in the adjacent bay there will be heavy negative bending moment over the end beam, which has got to be separately calculated and additional top reinforcements provided.

Mr. A. K. Datta (Calcutta) :—I would like to make a little suggestion about the figure on page 28 (j). Here the joist has been shown as plain joist over which a reinforced cement concrete slab has been placed. What we usually observe is that when a steam roller or a vehicle goes over a bridge like this, there is always some vibration caused in the joist, which often causes cracks in the slab. So the better practice will be, in such cases, to combine the joist with the slab. In that case there will be less jarring on the slab. Also, the section of the joist can be reduced. When the slab and the joist will be bound together with a few stirrups, there

will be combined action. As such, the section can be reduced, (see figure A). In some cases a little additional reinforcement A_t will also make up for this deficient area, (see figure B). In our standard designs, too, it will be a better thing to show the slab and the joist as a combined one. In that case there will be less jarring. On account of this reinforced concrete slab, the strength of the joist on the top also will be very considerably increased. Personally I have made a lot of actual experiments on that line to see how much extra strength we can have by combining a slab with the joist. For example, I tried an 8-inch \times 4-inch joist on 22 feet span with a 6-inch reinforced brick slab combined in this way; that stood quite a decent amount of load. I do not remember exactly but it can be seen in my book on Experimental Researches on Reinforced Brickwork* (page 7). In such cases I tried to find out from the Tata people if they could roll steel beams with bigger sections of steel at the bottom flange and smaller sections at the top flange, (see figure C) with the idea, that such beams can be used for different kinds of reinforcement for bridges, etc., in combination with the slab. Of course, they did not agree. The next thing was, whether we could have similar beams with smaller sections at the top and bigger at the bottom with a few strands working as stirrups, (see figure D), thereby reducing the amount of steel practically to half. Of course, we could not get that too. There will be great economy in steel beams if steel manufacturers in India take up these ideas and manufacture steel beams on these lines.

In any case, in the present case, as in figure on page 28 (j), it would be better to combine the joist with the slab and include a part of the joist in the slab, so that there will be better combined action.

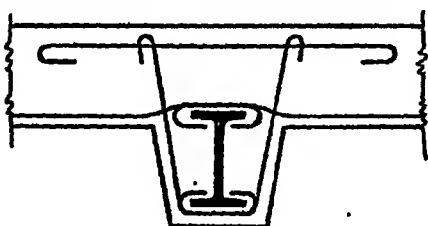


FIG. A.

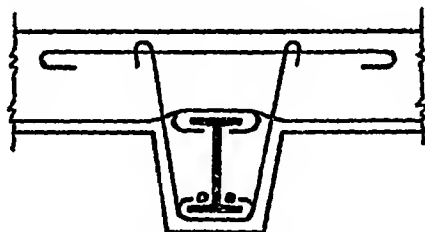


FIG. B.

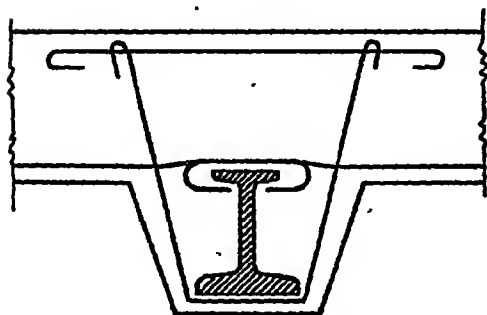


FIG. C.

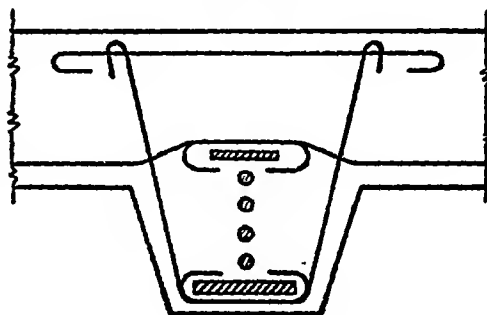


FIG. D.

* Failed with a load of 14.3 tons, whereas ordinary 8-inch \times 4-inch beam can stand a load of 6.22 tons at a stress at elastic limit.

Mr. H. Hughes (Burma):—With reference to diagram 4, page 28 (j), I would like to enquire how the Author arranged the false work for the cantilevered part of the structure. For the type of bridges on which rolled steel beams and a concrete slab are used, it is very easy to fix the false work *between* the rolled steel beams as it can be supported on their bottom flanges. For the cantilevered portion this arrangement is not possible but if the height from the bed of the stream to the road is not great, it may be possible to arrange supports.

The case to which I refer may be when either due to the height from the stream bed to road being considerable, or due to other causes, it may not be convenient to fix supports in the stream bed for the cantilevered section.

Mr. Brij Mohan Lal (Punjab):— I am very thankful for the valuable criticism and suggestions on my paper.

First of all I shall take up the comments of Mr. Jagdish Prasad. I agree with his remarks that for a span of 3 feet, a slab of a thickness of less than 7 inches can be made safe for bond-stresses by choosing smaller bars at closer spacing. He has also remarked that the maximum bending moment for the $2\frac{1}{2}$ feet cantilever in case of bridges with Rolled Steel Beams will be as much as 73,812 inch pounds instead of 31,582. I have also now calculated it in detail and find that it will be about 25,000 inch pounds for which a thickness of 7 inches is sufficient.

As the width of the R.S. Beams is 6 inches or more, except for spans of less than 14 feet, the span for dead load should be taken as 2 feet 3 inches instead of $2\frac{1}{2}$ feet. The span for distributed live load will be $1\frac{1}{2}$ feet. Regarding knife-edge load, I am of opinion that only half of the standard loading should be taken in the case of $2\frac{1}{2}$ feet cantilever, because only the weight of half of a vehicle can possibly come on this portion. The knife-edge load represents the excess in a standard train of the heavy axle over the other axles. As only half the weight of the heavy axle can possibly bear on the cantilevered portion, it is quite reasonable to assume the knife-edge load as 3 tons only. Moreover its points of application should be assumed about 9 inches from the edge of the beam. Similarly the total distributed live load should be taken as only 3.4 tons instead of 6.8 tons, as only half the weight of the vehicles can possibly come on the cantilevered portion. The detailed bending moment will then be as below :—

- (i) Bending moment due to distributed live load

$$= \frac{WL}{2} = \frac{0.34 \times 1\frac{1}{2} \times 2240}{2} = 571 \text{ foot pounds.}$$
- (ii) Bending moment due to concentrated live load at end of cantilever

$$= WL = 0.3 \times \frac{3}{4} \times 2240 = 504 \text{ foot pounds.}$$
- (iii) Bending moment due to dead load of R. C. slab

$$= \frac{WL}{2} = (2\frac{1}{4} \times \frac{7}{12} \times 144) \frac{2.25}{2} = 212 \text{ foot pounds.}$$

- (iv) Bending moment due to dead load of wearing coat

$$= \frac{WL}{2} = 1\frac{1}{2} \times \frac{9}{12} \times 140 \times 1\frac{1}{2} \times \frac{1}{2} = 40 \text{ foot pounds.}$$
- (v) Bending moment due to dead load of curb

$$= WL = \frac{9}{12} \times \frac{1\frac{1}{2}}{12} \times 144 \times 1\frac{1}{2} = 253 \text{ foot pounds.}$$
- (vi) Bending moment due to railing

$$WL = 10 \times 2\frac{1}{2} = \underline{22 \text{ foot pounds.}}$$

Total bending moment 1602 foot pounds.

Impact allowance of 50 per cent on
 live load bending moment 538 foot pounds.

Total bending moment : 2140 foot pounds.

The spacing of beams as proposed by me is, therefore, suitable. Mr. Jagdish Prasad has also given a sketch of fixing the railing post to kerb for which I, thank him. I however, prefer a 9 inches wide kerb as it gives a more solid look, and can also serve as a side-walk at times.

Regarding the safe working stress for steel joists at 8 tons, it was assumed so in accordance with table IV page 92 of Indian Roads Congress Specification which allows 18,000 pounds equivalent to 8 tons. I have, however, no objection to assuming it as 7.5 tons in accordance with the table on page 28, which I agree is the more appropriate stress. This change would, however, make very little differences in the selected sizes of rolled steel beams.

Mr. Jagdish Prasad has also suggested that, for spans beyond 30 feet, it is not economical for T-Beams to be spaced 5 feet 6 inches apart. He has suggested three ribs instead of four. This point may be considered when revising type designs ; though I am not sure that it will make the design more economical.

Mr. Jagdish Prasad has also made certain remarks regarding the bed level shown in figure 6 on page 30 (j). The depth of foundations depends on a number of factors, namely depth of scour, kind of soil etc.. The figure H/5 will only hold for ordinary soil. As the design is only for average conditions, I do not think that the changes suggested by him are necessary. Alterations can always be made in the type design to suit any particular requirements.

2. A written communication* has been received from Mr. Murari Lal, Punjab, suggesting that slabs should also have been designed for one, two or three feet spans. He has also given detailed calculations for a two feet span slab. He has also stated that slab for these spans can be about 6 inches thick. When the type designs are revised, calculations will also be made for those smaller spans. Mr. Murari Lal is, however, not right in his calculations in making an allowance for the dispersion of the knife-edge load through the thickness of wearing coat and the slab. The

* These comments appear on pages 46 (j) to 52 (j)

main idea of fixing a knife-edge load is that it should be treated as a concentrated load, and should not be considered to be distributed by dispersion..

3. Mr. Mahapatra has objected to the tensile reinforcement being halved at the ends of a simply supported slab. But as the bending moment for a simply supported beam is maximum at the centre and reduces to zero at the supports, it is self-evident that the same tensile reinforcement is not required at the ends as at the centre. Therefore, it should be reduced to half from a point where only half its quantity will do. This point is at .15 of the span from the end. It is necessary to bend the remaining half to take up diagonal tension at the ends. Some more reinforcement is also given to provide for negative bending moments which may be produced due to the slab acting as a partially fixed beam.

4. Mr. Mahapatra has also objected to a cover of $1\frac{1}{2}$ inches of concrete below the reinforcement and has considered it excessive. In paragraph D 16. of Indian Roads Congress Specifications, a cover of 1 inch has been recommended for main reinforcing bars from the outside of the bars. The reinforcement bars are not less than $\frac{5}{8}$ inch diameter in any case; the minimum cover should be $\frac{15}{16}$ inch, which is only $\frac{3}{16}$ inch less than $1\frac{1}{2}$ inches. For the sake of simplicity in work, it has been kept as $1\frac{1}{2}$ inches; a cover of $1\frac{1}{2}$ inches is, therefore, not excessive.

5. Mr. Mahapatra has also objected to the distribution of a knife-edge load over a uniform area of 100 square feet for the purpose of calculating the surcharge load. The objection made by him is correct, but it is not necessary to be so accurate for calculating the height of surcharge, whose effect is very small on the size of the structure. From the figures on page 14 (j), it will be seen that out of a total vertical weight of 50,000 pounds, the weight due to surcharge is only 2,130 pounds. Therefore, it is unnecessary to calculate the surcharge separately for different heights of structures, and assumption of a uniform surcharge of $2\frac{1}{2}$ feet is good enough.

6. Rai Sahib Lala Fateh Chand has asked for a lot of information, some of which is outside the scope of the paper, and can be had from various treatises on bridges.

The railing should, in my opinion, be about 3 feet over the top of the wheel-guard, and generally consist of T-iron standards and galvanised pipes. Masonry railings are a bit too heavy. As already shown in my reply to Mr. Jagdish Prasad, the weight of railing has no appreciable effect on the design of the cantilever. The wearing coat should be 3-inch cement concrete in case of *kutchra* as well as *pucca* roads. No cushion is necessary between the slab and the wearing coat. Designs for R. S. Beams encased in cement concrete have not been considered in this paper, and in my opinion, cannot work out cheaper than T-Beams. A cement mortar of 1 to 6 is quite good enough for all work above normal water level of the stream. It is only a matter of choice whether 1 to 5 cement mortar be used or 1 to 6.

As regards the distribution of load through the thickness of slab, I have not considered any further distribution of load in the paper, as I do

not consider it necessary, after having fixed up the standard loading according to Indian Roads Congress Specifications. The distribution reinforcement in slabs has been fixed as 20 per cent of the main tensile reinforcement on page 102 of the Indian Roads Congress Specifications. It is, however, to be brought to notice that the Ministry of Transport has laid down a much greater percentage of distribution steel *vide* Appendix I (b) of Memorandum on the Lay-out and Construction of Roads. A percentage varying from 40 per cent to 60 per cent for spans 4 feet to 10 feet, with a maximum of 0.5 square inch per foot has been suggested therein for steel parallel to the supports. Shear has been carefully calculated for in the design for slabs as well as for T-Beams. The value of 'j' for T-Beams has been taken from graphs on page 57 of the book on 'Reinforced Bridge Design' by Messrs. Chattoe and Adams. Negative bending moments at supports in simple slabs, and over R. S. Beams in continuous slabs has been provided for by bending up alternate bars of tensile reinforcement and providing some additional bars in case of intermediate R. S. Beams. Thus provision has been made for negative bending moment equal to the maximum positive bending moment over top of R. S. Beams. Messrs. Chattoe and Adams, however, recommend the same reinforcement in top as at bottom in slabs in all cases to take up all possible shear and bond-stresses. This, however, appears excessive. Regarding complete influence line diagrams for various positions of loading, it is stated, that they do not appear necessary for bridges of short spans.

Mr. Ayyar has referred to the assumption of dispersion of concentrated load. In my paper, however, no dispersion of load has been at all considered, and, therefore, calculations have been made for the concentrated load in the worst position. It is, therefore, not necessary either to increase the thickness of slab at the end or design the wheel-guard as an inverted beam.

Mr. Nambiar has suggested the calculation of tensile stress in the lower layer of reinforcement bars in T-Beams to see that it does not exceed the safe limit. It is, however, pointed out to him that the tensile stress will decrease as depth increases and will, therefore, not exceed 18,000 pounds. Regarding his suggestion for calculating end-beam separately for a heavier bending moment, it is pointed out that due to the standard loading consisting of a knife-edge load and a distributed load, it is not necessary to do so.

Mr. Datta has pointed out that where a slab is directly put over an R. S. Joist, the joist vibrates due to heavy rolling load, and the slab cracks. No such cracks have, however, so far come to the notice of the Author. As already pointed out in the reply to Rai Sahib Lala Fateh Chand, a T-Beam is cheaper than R. S. Joists embedded in concrete. The idea of 'slab over rolled steel beams' construction is ease and simplicity in execution of work without much expence on shuttering. Embedding of R. S. Joists in concrete, however, involves a good deal of expenditure on shuttering.

Mr. Hughes has referred to the difficulty of shuttering for the cantilevered portion in case of considerable height from the stream bed to the road surface. This could easily be overcome by providing an additional beam of a lighter section at the ends under the wheel-guard for purposes of shuttering which could be removed after the maturing of concrete.

I agree with the objection of Mr. Raghavachary that in case of slabs upto 10 feet span, the bond-stress at the ends would exceed the limit of 200 pounds, as half the rods are cranked. It is, however, necessary to change the number of rods for spans 4 feet to 6 feet only, as suggested by Mr. Raghavachary. For spans bigger than 6 feet, the bond-stress would not exceed 236 pounds which may be allowed. Hool has permitted an excess of as much as 33 per cent over permissible unit bond-stress at ends of beams where other rods are bent up *vide* page 120 of Volume I of his Reinforced Concrete Construction (1917 edition).

There appears no objection to crank each rod at one end, and keep it straight at the other end placing them alternately with straight and bent ends. Regarding continuous spans, it is stated that bending moments for interior and end-spans only have been calculated. The required thickness of slab can be chosen for each particular case. There is no doubt that it is decidedly convenient to use the same thickness of slab for all spans.

In case of T-Beams a suggestion has been made by him to increase the fillets to 6 inches \times 6 inches. It does not appear necessary to do so, as the effective span of the slab must be taken as between centres of ribs instead of as the clear space between them, so that the slab may be designed as continuous. The cantilever portion is already safe with thickness as 7 inches without support from fillets. Negative bending moment has been provided for at the supports by bending some end-bars. It is regretted that calculations for bond-stress were left out for T-Beams. It will not, however, exceed the permissible limit. It has been suggested that the width of the rib could be reduced to a limit which would allow the permissible spacing of rods. But if breadth will be reduced, shear will increase. It is, therefore, not advisable to reduce the breadth of ribs. The points of bending of reinforcement bars in T-Beams as shown in figure 5, are applicable to all T-Beams. This arrangement has been taken from the recommendation made in Military Engineering Services Hand-Book. It will certainly, however, be better to calculate the points of bending correctly for each span. Mr. Raghavachary is thanked for his going through the paper so carefully and suggesting very useful amendments.

The members who have contributed to the discussions are again thanked for the trouble taken by them and making such useful suggestions.

CORRESPONDENCE

1. Comments made by Mr. Murari Lal (Punjab), by post on Paper No. J.

Although the calculations involved in the design of the Reinforced Concrete Slab become simple enough as soon as the arrangement and intensity of loading is made known, yet the efforts to compile a handy table of useful data for the construction of small span culverts entail quite a good deal of labour to work out details and the Author deserves to be congratulated for being able to put in the hand of engineers a pamphlet which will

enable them to construct their culverts without going through laborious calculations.

I would only add that the table should be made complete by including culverts of small spans of 1, 2 and 3 feet as these have been omitted in the table and because majority of our culverts on roads consist of spans of two or three feet. The Author, according to his table III, would have us assume that 7 inches thickness is the minimum thickness to be used for Reinforced Concrete slabs of culverts of even two or three feet span but this is rather extravagant, as in actual practice slabs of lesser thickness, of 5 inches and 6 inches, have been used for 2 feet and 3 feet span culverts respectively and have been found to stand the test of time and traffic over our arterial roads where these have been subjected to loading of heavy steam road-rollers and military tanks.

Now I will try to show that these lesser thicknesses are ample even for the loads specified in the Indian Roads Congress standard loading which has been adopted in the compilation of Table III by the Author.

Take an example of 2 feet culvert;

Effective span = 2 feet 6 inches.

Bending moment per foot width of slab for live load is as below:—

$$\begin{aligned} \text{Due to distributed load} &= \frac{.68 \times 2240 \times 2.5}{8} \text{ foot pounds.} \\ &= 5712 \text{ inch pounds.} \end{aligned}$$

Knife-edge load of .6 tons as applied on the top of road surface will distribute itself at an angle of dispersion of 45 degrees through the wearing surface and the reinforced concrete slab, length-wise. Let this thickness in the case be 3 inches of wearing coat plus 5 inches of reinforced concrete slab or a total of 8 inches. Therefore, the knife-edge load of .6 ton will be distributed over a length of 2×8 inches = 16 inches.

$$\text{The bending moment, therefore, due to knife-edge load} = \frac{W}{2} = \left(\frac{L}{2} - \frac{1}{4} \right)$$

where W = knife-edge load per foot width:

L = effective span.

1 = spread of load.

$$\begin{aligned} \text{Bending Moment} &= \frac{.6 \times 2240 \times 12}{2} \left(\frac{2.5}{2} - \frac{1'-4''}{4} \right) \\ &= 7392 \text{ inch pounds.} \end{aligned}$$

$$\begin{aligned} \text{Therefore, Total Bending Moment} &= 5712 + 7392 \text{ inch pounds} \\ &= 13104 \text{ inch pounds.} \end{aligned}$$

Adding 50 per cent for impact;

$$\begin{aligned} \text{Total Bending Moment for live load} &= 13104 \times \frac{3}{2} \\ &= 19656 \text{ inch pounds.} \end{aligned}$$

Bending Moment per foot width of slab due to dead load is as below:—

$$\begin{aligned} \text{Weight of one foot width of 5-inch thick slabs} &= \frac{5}{12} \times 144 \times 1 \\ &= 60 \text{ pounds.} \end{aligned}$$

$$\begin{aligned} \text{Weight of the 3-inches cement concrete wearing coat} &= \frac{3}{12} \times 140 \times 1 = 36 \text{ pounds} \\ \text{Total} &= 96 \text{ pounds.} \end{aligned}$$

$$\text{Therefore, Bending Moment due to dead load} = \frac{96 \times 2.5 \times 2.5 \times 12}{8} \\ = 900 \text{ inch pounds.}$$

$$\text{Total Bending Moment due to dead and live loads} = 19656 + 900. \\ = 20556 \text{ inch pounds.}$$

$$\text{Now } M_R = R \times b \times d^2$$

where M_R is the moment of resistance of slab

and $R = 137$ for a percentage of steel of .0089 to area of concrete,

b representing the breadth of the slab.

$$\therefore d, \text{ the effective depth of slab} = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{20556}{137 \times 12}} = \sqrt{\frac{20556}{1644}} \\ = 3.5 \text{ inches.}$$

Let us keep the effective depth at 3.75 inches; adding a cover of 1.25 inches:

$$\text{Then the total depth of slab} = 3.75 + 1.25 = 5 \text{ inches,}$$

$$\text{Area of steel required} = .0089 \times 3.75 \times 12 \\ = .40 \text{ square inches}$$

Use 4 Nos. 3/8" bars, 3 inches apart (area = .44 square inches).

We should now test the slab for bond and shear stress.

Shear:

$$\text{Due to dead load of slab} = 2.5 \times \frac{5}{12} \times 144 = 150 \text{ pounds}$$

$$\text{Due to wearing coat} = 2.5 \times \frac{3}{12} \times 144 = 90 \text{ pounds}$$

$$\text{Total} = 240 \text{ pounds}$$

$$\text{Reaction on one support due to the above} = \frac{240}{2} = 120 \text{ pounds.}$$

Due to distributed live load

$$\text{Reaction on one support} = \frac{.34 \times 2.5 \times 2240 \times 1.5}{10 \times 2} \\ = 134 \text{ pounds}$$

Due to knife-edge load:—

The knife-edge load when it is just loading the edge, distributes itself over 8 inches due to dispersion through concrete and slab.

$$\text{Hence, reaction on the near support} = .9 \times 2240 \times 1.5 \left(\frac{24 - \frac{8}{2}}{24} \right) \\ = .9 \times 2240 \times 1.5 \times \frac{23}{24} \\ = 2520 \text{ pounds}$$

$$\text{Total shear} = V = 2520 + 134 + 120 = 2774 \text{ pounds.}$$

$$\therefore \text{Shear-stress } v = \frac{V}{b.j.d.} = \frac{2774}{12 \times 3.75 \times .857} \\ = 72 \text{ pounds}$$

This is less than the permissible stress of 75 pounds, *vide* Table 1 page 89 of the Standard Specification.

49 (j)

$$\begin{aligned} \text{Bond-stress } u &= \frac{V}{j d \leq 0} = \frac{2774}{.857 \times 3.75 \times 4 \times \frac{22 \times 8}{7 \times 8}} \\ &= \frac{2774}{15.2} \\ &= 182 \text{ pounds.} \end{aligned}$$

This is less than twice 100 pounds and hence the slab is safe for bond-stress too.

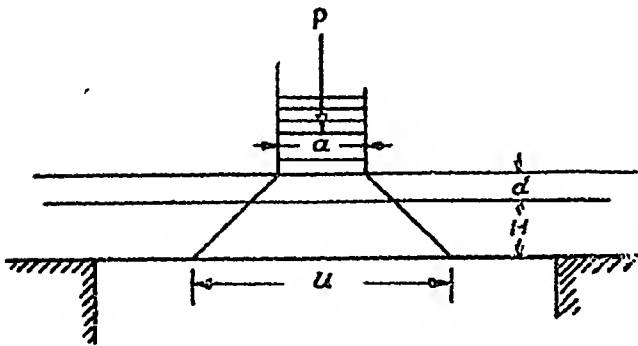
We can now compare the thickness of 5 inches with the thickness arrived at by taking into consideration other standard methods of designing the road slab by the method of dispersion.

These are :

1. Pigeaud's method as described in the Reinforced Concrete Bridges "W.L. Scott" pages 141 to 155.
2. Punjab Buildings and Roads Branch, 1929 Reinforced Concrete Committee method.

Pigeaud's method :—

The wheel load Concentrated on the contact area $a \times b$ is assumed to spread through the road crust and slab over a loaded area $u \times v$.

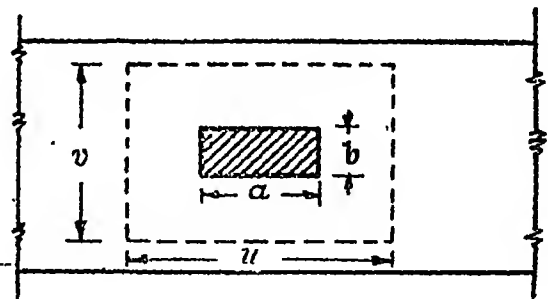


$$\text{where } u = \sqrt{(a + 2d)^2 + H^2}$$

$$\text{and } v = \sqrt{(b + 2d)^2 + H^2}$$

d being the depth of road crust.
= 3 inches

and H being the assumed
thickness of slab = 5 inches.



Take a 15 ton-roller as the heaviest load that can come upon a 2-feet span culvert,

Weight of each rear wheel = 13400 pounds.

Add 25 percent for impact = 3350 pounds.

Total 16750 pounds.

Say 16800 pounds.

This weight is greater than the maximum wheel-load adopted in the United States and France (See "Reinforced Concrete Bridges" by W. L. Scott).

Tyre width of hind roller = 20 inches = a

Area of contact parallel to slab span = 3 inches = b.

$$\therefore v = \sqrt{(3+2 \times 3)^2 + 5^2} = \sqrt{81+25} = \sqrt{106} = 10.4$$

$$u = \sqrt{(20+2 \times 3)^2 + 5^2} = \sqrt{676+25} = \sqrt{701} = 26.4.$$

$$\text{Now } \frac{U}{L} = \frac{10.4}{30} = .38 \quad \therefore m_1 = 1.6$$

$$\text{and } \frac{V}{L} = \frac{26.4}{30} = .88 \quad \therefore m_2 = 0.5$$

(See page 104 and 105 of 'Reinforced Concrete Bridges' by W. L. Scott).

Therefore, bending moment in the direction of span due to live load will be,

$m_1 \times P = 1.6 \times 16750 = 26800$ inch-pounds and in the direction at right angles to span will be,

$m_2 \times P = .5 \times 16750 = 8,375$ inch pounds.

Bending moment due to dead load as already worked out = 900 inch-pounds.

Therefore, total B.M. = $26800 + 900 = 27700$ inch pounds.

$$\text{and } d = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{27700}{12 \times 137}} = \sqrt{16.8} = 4.1 \text{ inches}$$

Allow a cover of .9 inch.

\therefore Total depth = $4.1 + .9 = 5$ inches. It is sufficient.

Area of steel = $.0089 \times 4.1 \times 12 = .44$ Square inches.

Use 4 No. 3/8-inch bars 3 inches apart area = .44 square inches.

Total positive bending moment in a direction at right angles to span = $16750 \times .5 = 8375$ inch-pounds.

And the lever arm = $4.1 \times .88 = 3.6$ inches

$$\begin{aligned} \text{Hence area of steel per foot width} &= \frac{8375}{18000 \times 3.6} \\ &= \frac{8375}{64800} = .13 \text{ square inches} \end{aligned}$$

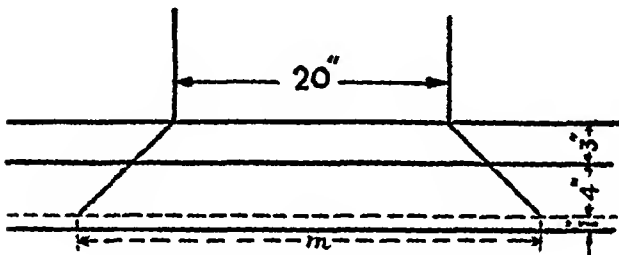
Use $3/8''$ bars, 9 inches apart.

PUNJAB P.W.D. REINFORCED
COMMITTEE METHOD.

Live load as assumed in Fig-
eaud's method due to a 15 ton
roller including impact = 16750
pounds on a wheel.

Loaded length at

right angles to support (n) = $3 + 2(3 + 4) = 17$ inches.



Loaded length

parallel to support

$$(m) = 20 + 2(3 + 4)$$

$$= 34 \text{ inches}$$

Standard width for

Bending Moment, (l_m),

$$= 1/3 (1 + n) + m.$$

$$= 1/3 (24 + 17) + 34$$

$$= 48 \text{ inches.}$$

\therefore Live load per foot width of slab

$$= \frac{16750 \times 12}{48} = 4190 \text{ pounds}$$

$$\therefore \text{ Bending Moment for live load} = \frac{W}{2} \left(\frac{1}{2} - \frac{n}{4} \right)$$

$$= \frac{4190}{2} \left(\frac{30}{2} - \frac{17}{4} \right)$$

$$= \frac{4190}{2} \times \frac{43}{4}$$

$$= 22520 \text{ inch pounds.}$$

Bending Moment for dead load as calculated in previous methods
= 900 inch-pounds.

$$\text{Total B.M.} = 22520 + 900 = 23420 \text{ inch-pounds.}$$

$$d = \sqrt{\frac{23420}{12 \times 137}} = \sqrt{14.2} = 3.8 \text{ say } 4 \text{ inches.}$$

Allow a cover of 1 inch which is ample and hence total depth = 5 inches.

Area of steel, therefore, is the same as worked out in previous example,
i.e., $\frac{3}{8}$ inch bars at 3 inch centres.

Now we proceed to find the shear stress.

$$\text{Stressed width} = n + m + 2d$$

$$= 17 + 34 + 10 = 61 \text{ inches.}$$

As this is more than half the width of 'standard train of loading'
(which is 5 feet), therefore, 5 feet shall be adopted,

$$\therefore \text{Live load per foot width of shear} = \frac{16750 \times 12}{60} = 3350 \text{ pounds.}$$

Shear is maximum when one edge of loaded area just touches the support.

$$\begin{aligned} \therefore V &= 3350 \left(\frac{24 - 8\frac{1}{2}}{24} \right) \\ &= 3350 \times \frac{15\frac{1}{2}}{24} = \frac{103850}{48} = 2164 \text{ pounds.} \end{aligned}$$

Add shear for dead load as worked out before = 120 pounds.

Total shear = 2284 pounds.

$$\begin{aligned} \text{Unit shear} = v &= \frac{V}{b_j d} = \frac{2284}{12 \times 4 \times .857} = \frac{2284}{41.136} \\ &= 56 \text{ pounds, which is safe.} \end{aligned}$$

Bond stress = $\frac{2284}{.857 \times 4 \times 4 \times 22 \times \frac{1}{8}} = 146$ pounds, which is less than 200 pounds and hence the slab is safe against shear as well as bond-stress.

By adopting these lesser thicknesses, we shall not only be safe but effect, in majority of the culverts, a saving of from 10 to 30 percent.

2. Comments made by Mr. K. S. Raghavachary (Madras), by post, on Paper No. J.

The Author deserves the gratitude of the members for the useful tables prepared by him for the rapid design of bridges of spans varying from four feet to forty feet thus avoiding elaborate calculations every time a design has to be made. A few points that seem to require further elucidation are noted below.

Slab Bridges :— The bond-stress noted in the last column of Table III has been calculated on the assumption that all the tensile rods at bottom are carried straight to the supports. But in Figure 3, it is shown that half the rods are cranked. Hence only half the number of rods will be available for bond at support, and the bond-stresses developed would, therefore, be double the figures noted in Table III. The bond-stresses for spans 4, 5, 6, 7, and 10 feet, would exceed the permissible 200 pounds, for hooked rods. Instead of using large-size rods, smaller-size rods are desirable, as they would keep down the bond-stress.

Taking the four feet span, by using 3/8-inch rods at 2½-inch centres the area of steel is the same (0.59 square inch per foot width) but the bond-stress is reduced to 120 pounds if all the rods are taken straight. In this case one third the number of rods could be cranked, the maximum bond-stress being 180 pounds per square inch. In the case of five feet span, half inch rods at 3½-inch centres and giving the same area of 0.67 square inch

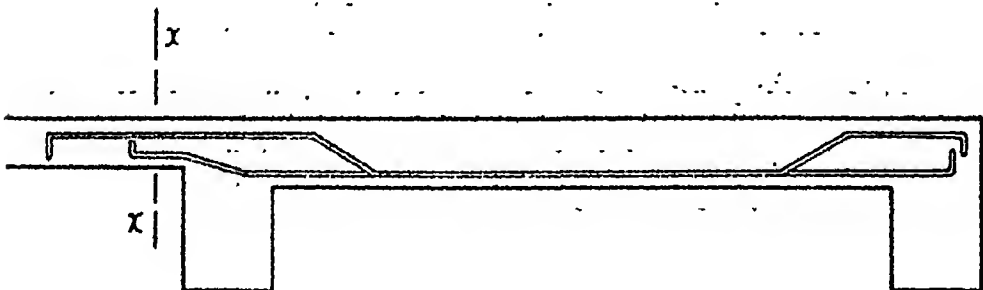
per foot width could be used. One third the number could be cranked and the bond-stress would be limited to 200 pounds per square inch in the remaining bars carried to the support.

For spans of 6 feet to 8 feet, $\frac{1}{2}$ inch diameter rods and for spans of 9 feet to 13 feet, $\frac{3}{4}$ inch rods are suggested. For spans of 14 feet and more, $\frac{7}{8}$ inch rods could be used. In these cases, half the number could be cranked for negative bending moment (due to partial fixity in construction etc.) and for diagonal tension. The bond-stress would still be within permissible limits at the supports.

Bending Rods :— I would like to suggest that the rods may be cranked at one end and straight at the other, instead of cranking every alternate bar at both ends. Instead of having two types of rods, it will do to have one kind. The arrangement is shown in the sketch, *vide* page 55 (j).

Continuous Spans :—In para 8, in the case of continuous spans, a slab thickness of $8\frac{1}{2}$ inches for interior spans and 9 inches for the end span is proposed by the Author. As the rods from the end spans have to be taken well into the interior span, the rods have to be slightly bent to provide the same amount of cover. In this connection, reference is made to Manning's Reinforced Concrete Design pages 193-194, an extract of which is reproduced here for ready reference.

" Dealing now with the next method of meeting the increased moments, *i.e.*, by thickening the end span, it is clear that we can thus easily cover the moments near mid-span, but difficulty arises at the support. Figure (below) where the difference in thickness has been exaggerated, illustrates this point. It will be seen that the bottom bars cannot be taken straight through from span to span and the additional thickness is not effective to resist the moment at the support, for section x - x in the figure is only equal in thickness to the interior spans. The section must, therefore, be checked for $\frac{WL^2}{10}$."



I would like to suggest that a uniform thickness of 9 inches be adopted for all the spans and the reinforcements reduced in the interior spans if desired. This will also obviate the necessity for providing extra rods for the negative bending moment of $WL^2/10$ at the first interior support.

T-Beams (*vide* paragraph 10 of the paper):—

- (a) It is suggested that fillets may be 6 inches × 6 inches so that advantage may be taken to design the slab by considering the clear span between the ribs as effective span. In the case of end T-beams, this will be helpful in providing increased thickness of deck-slab for the cantilever portion.
- (b) The Author has not indicated that the negative bending moment due to partial restraint at the supports has been taken into account. It is desirable that rods are provided at the top to take a negative bending moment of $\frac{WL^2}{16}$.
- (c) Bond-stress has not, been calculated in the example of T-beam for 30 feet span. It is, however, seen that bond-stress at support is within limits (117 pounds) with the three, one and one-fourth inch bars taken straight. It is hoped that the bond-stress is within limits for other spans also, in Table VI.
- (d) For spans up to about 33 feet, where rods can be secured in one length, without overlap, the width of rib could be reduced consistent with the spacing recommended in clauses D.16 and D.18 of the Indian Roads Congress specifications and with the best proportions of height to width of rib. For the thirty feet span, rib width may be $12\frac{1}{2}$ inches (instead of 14 inches) even allowing a spacing of $1\frac{1}{2}$ -inch diameters between rods and a clear cover of 2 inches beyond stirrups. If one diameter alone is allowed in this case, where splicing could be avoided, the width could be further reduced by another $1\frac{1}{4}$ inch. The dead weight could thus be reduced.
- (e) I would like to enquire from the Author whether the points of bending as shown in figure 5 are applicable to all T-beams given in Table VI, and whether there are particular reasons for the recommendations given. It is presumed that the bending moment at the points have been investigated to satisfy that the remaining bars are sufficient to resist the bending moment.

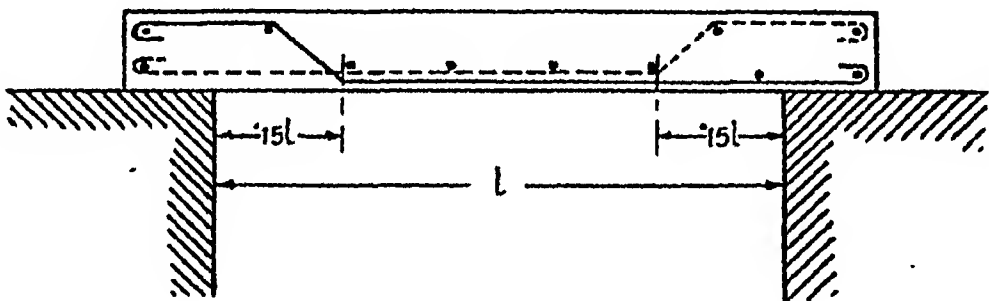
Though the bent-up bars are not relied upon by the Author to take up diagonal tension, in the example worked out, it would seem better if they are spaced at a distance not exceeding two-third 'd' along the neutral plane, so that they will effectively add to the shear strength of the beam.

R. C. DECK SLAB

SINGLE SPAN

FREELY SUPPORTED

ARRANGEMENT OF REINFORCEMENT



N. B.—Rods are shown diagrammatically one over the other, though they are in the same horizontal plane.

Friday, February 17, 1939.

PAPERS M AND K (II).

Mr. S. G. Stubbs, (President):—I propose taking the Papers M "Ribbon Development" and K (II) "Lay-out of Roads" together. Will Mr. Murrell kindly take the Chair in place of Mr. Ormerod, who is suffering from a throat infection.

Mr. W. L. Murrell, (Chairman):—I first call upon Lt.-Col. H. C. Smith, to introduce the Paper M "Ribbon Development" by Mr. Trollip; and then Mr. R. Trevor-Jones will introduce his Paper K (II) "Lay-out of Roads."

The following two papers were then taken as read:—

CORRIGENDA TO PAPER NO. M.

As a result of further research the author considers that the following corrections have become necessary in his paper.

Page 2 (m).

Paragraph 4.—Disadvantages of Ribbon Development.—Instead of "one of the main considerations" read "one consideration".

Paragraph 8.—Instead of "more crowded with local traffic" say "more crowded with both moving and standing local traffic."

After "through traffic is seriously handicapped". add "Ingress to and egress from private properties cause hazards and delays to through traffic."

Paragraph 9.—Delete.

Paragraph 10.—After "slow down traffic" add "and reduce the capacity of the road considerably".

Paragraph 11.—Instead of "is increased fourfold" say "is increased greatly".

Page 7 (m).—Ultimate Width of the Road.

Paragraph 9.—insert after "the volume"—"and types".

Paragraph 11.—Instead of "challenged the practicability of an operating speed of 100 miles per hour" say "challenged the practicability of a general operating speed of 100 miles per hour".

Page 8 (m).

Paragraph 5.—Foreground Vision.—After "as the speed of driving increases, the" add the following:—"driver concentrates his attention and focusses his eyes further and further ahead, hence the".

Paragraph 7.—Peripheral Vision.—After "as the speed increases, the angle of vision" add "or of visual attention".

Page 9 (m).

Paragraph 3.—Instead of "for visibility purposes" say "for sterilizing and control purposes".

Paragraph 5.—Re-write this entirely as follows:—

(a) *Perception Time.*—The time interval which drivers take to realise the necessity for using their brakes.

(b) *Reaction Time.*—The time interval between the realisation of the necessity for using brakes and the application of the brakes.

(c) *Braking Time.*—The time interval between the application of the brakes and the stopping of the vehicle.

Paragraph 6.—The Highway of the Future.—Insert "main trunk" after "it is suggested that the cross section of the".

Page 13 (m).—Bye-Pass Roads:—

Paragraph 6.—add "(c) Delays the through traffic unnecessarily".

Page 14 (m).—Revise clause 5 to read as follows:—

"5. Access to the bye-pass road should be carefully limited, i.e., there should be few cross roads or private entrances".

Clause 6.—Instead of "100 per cent" say "a maximum".

Service Roads.—Amend clause 2 as follows:—

"The carriageway of the service road should be sufficient to accommodate one parking lane of 8 feet and two traffic lanes, i.e., a minimum width of 28 feet".

PAPER No. M.

RIBBON DEVELOPMENT

By

A. S. TROLLIP, Joint Honorary General Secretary,
The Safety First Association of India.

SYNOPSIS.

	Page.
<i>Ribbon Development.—Its Disadvantages and Advantages ...</i>	... 2 (m)
<i>What is to be controlled.—Access, Obstruction to view, Corner Visibility, Parking, Siting of Advertisements and Petrol & Service Stations ...</i>	3 (m)
<i>Width of the Road ...</i>	... 7 (m)
<i>The Highway of the future ...</i>	... 9 (m)
<i>What other countries have done.—English Ribbon Development Act ; American Highway Zoning ...</i>	... 11 (m)
<i>By-pass Roads ...</i>	... 13 (m)
<i>Service Roads ...</i>	... 14 (m)
<i>Group Development ...</i>	... 15 (m)
<i>Finance ...</i>	... 16 (m)
<i>What should be done in India ...</i>	... 16 (m)

RIBBON DEVELOPMENT.

Where Highway Authorities do not control the frontages of roads, new houses spring up alongside and stretch out into the country in long untidy rows. This is called Ribbon Development because of the straggling strips of buildings that are scattered along the main road which passes through the town.

The Authorities often find it necessary to construct an arterial or bye-pass road for the express purpose of facilitating through traffic, which would otherwise have to pass through the congested road that passes through the town proper. If control is not exercised in time to restrict the erection of buildings along this new arterial road, the main purpose for which it was constructed will be frustrated. This fresh Ribbon Development will again hinder through traffic. The second state is obviously worse than the first, since there has been a waste of public money in building the arterial road.

Ribbon Development is sometimes referred to as "Linear Development" or "Strip Development".

Disadvantage of Ribbon Development.—1. One of the main considerations which forced the Highway Authorities in Europe and America to restrict Ribbon Development was that scattered buildings along the highway destroy and deface the beauty of the countryside.

2. Houses built along the main thoroughfare of a town can be neither pleasant nor healthy to live in, on account of the noise and dust caused by the traffic.

As new houses are built they get farther and farther away from the town. This causes inconvenience and increased cost of transportation to the worker, and at the same time decreases his available energy for work.

There is difficulty in providing buildings for schools, shopping, and public recreation which will be within easy reach of those who occupy houses at the extremities of the Ribbon Development.

3. If Ribbon Development is not restricted, the main roads become more and more crowded with local traffic, and through traffic is seriously handicapped. This makes for traffic congestion and road accidents.

Ribbon Development also necessitates the introduction of cross roads for providing access to buildings erected on back land.

The lack of proper control of frontages, access and crossways, due to Ribbon Development, not only tends to slow down traffic but also causes frequent accidents.

4. The cost of Public Services, i.e., water, drainage, gas, electricity, telephone, etc., is increased fourfold in areas of Ribbon Development. Where there is group development on the other hand, not only is the cost of Public Services considerably lower, but the works can be better planned out, more economically constructed and more easily maintained.

Control Imperative.—It is therefore best for all concerned that the Highway Authorities should exercise timely and proper control over the frontages of roads to restrict Ribbon Development, and that the Planning Authorities should immediately design schemes which will enable those who

wish to erect new buildings near a growing town to do so on the lines of Group Development—for Ribbon Development *must* stop.

WHAT IS TO BE CONTROLLED ?

Motor vehicle drivers usually govern their speeds and driving practices by what they see and understand. On the open road, with few intersections and unobstructed view, they may drive at quite uniform speed for miles. On city streets, however, with frequent intersections and varying degrees of restriction of view, speeds must be more irregular to conform with the variations in hazards which these conditions create.

When, upon approaching intersections, drivers are able quickly to see and to understand the hazards which exist, they control their speeds accordingly. They approach at speeds from which they can slow down or stop as may be necessary to prevent collisions with vehicles they can see on the intersecting streets. If, however, a situation is complex and the driver cannot readily understand it, he may fail to see a vehicle arriving unexpectedly or at a higher speed than he expected, and a collision results because he has not slowed down to a speed which will enable him to avoid an accident.

It is therefore necessary to control :—

- (a) Access to highways ;
- (b) Obstruction of view on the highway and its adjacent terrain ;
- (c) Corner visibility ;
- (d) Parking ;
- (e) The siting of advertisements ;
- (f) The siting of Petrol and Service Stations.

Access to Highways.—This includes intersecting roads, private drives, gates, stiles, and unfenced land, and is detrimental to safe and fast driving on the highway.

The principle of segregation is now well recognised. Fast moving traffic must be separated from slow moving traffic, and not clogged by the tardy movement of slow vehicles, pedestrians and animals.

Access to fast highways must be strictly denied in the interests of all traffic. Legislation to this effect is therefore necessary.

Obstruction of View.—It is necessary for the motorist to have an unobstructed view of the highway in a horizontal and vertical direction and to have a wide peripheral view of the adjacent terrain.

First, the motorist must be able to see the road well ahead of him to anticipate intelligently the movements of traffic ahead of him.

Secondly, the motorist must be able to see in good time whether any vehicles, pedestrians or animals are approaching his path from the adjacent terrain so that he can regulate his speed accordingly. It is therefore necessary that a sufficient strip of terrain adjacent to the highway should be controlled—the greater the design speed of the highway, the broader should be the width of controlled terrain. Legislation to provide for this is also urgently needed.

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Corners represent a special case of view obstruction which calls for more detailed consideration.

Corner Visibility.—When approaching an intersection or cross roads it is necessary that there should be no view obstruction at the corners so that drivers of vehicles approaching the intersection from different roads will see one another in good time to enable them to regulate their speed to avoid a collision.

Diagrammatically the position can be stated as follows :—

Figure 1 shows two vehicles A and B approaching a right-angled intersection at speeds of V_a and V_b respectively. In order that a driver may see other vehicles which are approaching the intersection it is necessary that there be no view obstruction at the corners of the cross road.

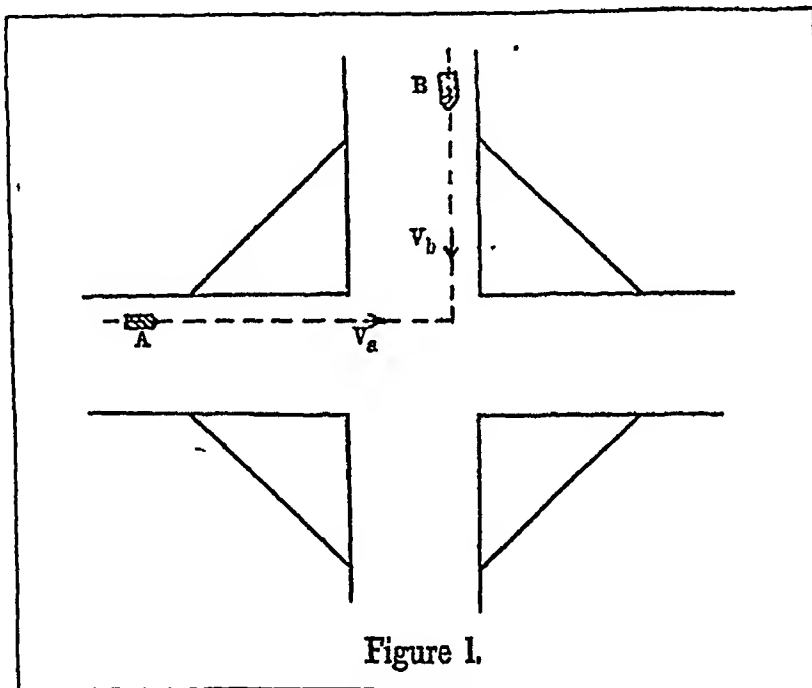


Figure 1.

This space is known as the Triangle of Visibility. The sides of the triangle are equal to the distances in which the vehicles could pull up.

The following table based upon a reaction time of $\frac{3}{4}$ th second and 40 per cent braking efficiency shows these distances for speeds varying from 10 to 70 miles per hour.

TABLE I.

Miles per hour.	10	20	30	40	50	60	70
Braking distance or length of sides of triangle of visibility in feet.	20	56	110	180	265	369	489

5 (m)

The nearer the vehicles are to the building line the greater the danger, and therefore the necessity of a bigger triangle of visibility.

If one vehicle is approaching the intersection as in trying to cut a corner or overtaking another vehicle, the condition will be still worse. This is illustrated in Figure 2, which shows two cars A and B following a line 8 feet away from the same corner :—

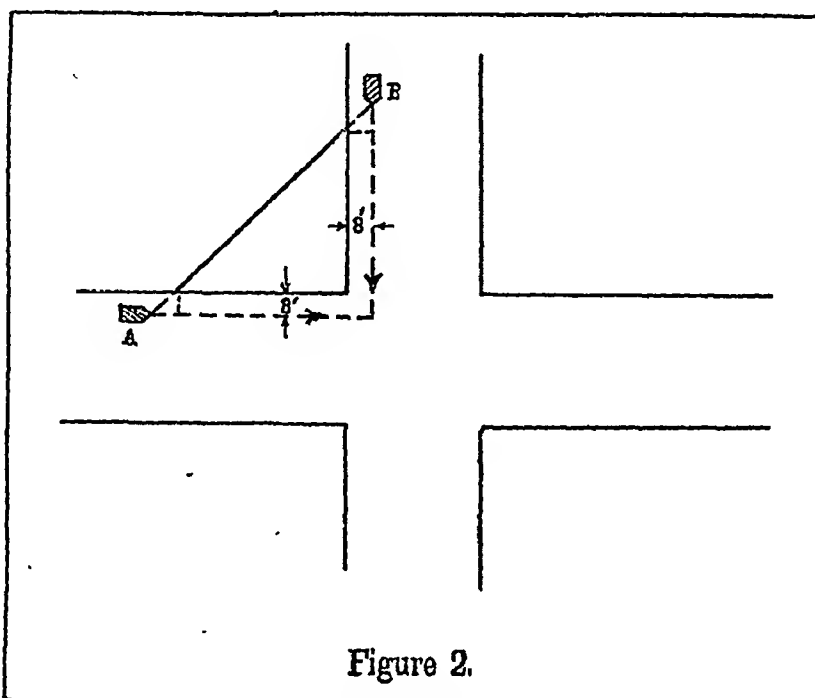


Figure 2.

If the speeds of the vehicles are 70 miles per hour each, then according to the table, the sides of the triangle of visibility will have to be 489 feet, and therefore the corner will require to be controlled for view obstruction for a distance of (489 feet—8 feet) 481 feet. This is a simple but incomplete solution to the problem. Other factors come into the question, *e.g.*, variation in braking distances on different road surfaces, drivers' reaction time, etc.

No doubt, 70 miles per hour is today a very high speed with which to approach a junction; but, we consider, it may be the speed of the future if access is limited.

When obstructions such as buildings, walls, trees, etc., are within this triangle of visibility and cannot be removed, it is necessary to install maximum speed limit signs to indicate to drivers the 'maximum safe approach speed'. This term, though not quite correct, conveys the meaning better than the correct technical term "critical speed".

The question arises as to how much land at the corner of the cross roads should have its use controlled. This, as we have shown, is dependent upon speed. The greater the approach speed the bigger the triangle required. On the other hand, it is necessary for reason of economy to keep the area required for corner visibility to a minimum.

Parking on the Highway.—(a) *Roadside Halts.*—Provision should be made in the layout of roads for roadside halts to be located at view-points and rest places, to enable the driver and his passengers to rest awhile and enjoy the scenery. To enable this to be done without causing danger and inconvenience to other users of the road, properly designed parking bays should be provided. If service facilities are also required they should be provided in accordance with the principles set out under Petrol Service Stations.

Other amenities might be included, *e.g.* first-aid equipment, telephone, a map of the district and a detailed map of the environment to enable those who understan*d* the use of maps to secure the maximum benefit from their visit.

It must be remembered that tourism is a national asset, and services such as have been indicated will enable the work of the highway engineer to be better appreciated and will pave the way for the approval of finance to improve his roads.

(b) *Garages.*—The parking of cars has been defined as a privileged use of the highway not contemplated by law. Parking reduces the width of carriageway available for main traffic. In business districts and in main streets the delay occasioned thereby is serious, and results in accidents.

The control lies in restricting parking and in the provision of garages. Streets are not the proper place to park vehicles: streets are meant for the movement of live vehicles and not for the storage of dead ones.

Places which attract the public in large numbers therefore require to be provided with garages to enable them to absorb their own traffic. Ample garage accommodation should be provided in all business quarters, for residents, office executives and visitors.

In the case of buildings which are built along main or through streets, ample accommodation by way of garages or compound space should be provided for residents' and visitors' cars.

Advertisements.—Billboard companies are quick to appropriate for their own profit the values created by public investment in the construction of highways. They line up their billboards along new roads almost as rapidly as they are built.

The billboard menace must be controlled.

They destroy the quiet loveliness and amenities of the picturesque countryside; they cheapen the approaches to the towns; they are a constant menace to life and limb, both as distracters of attention at danger points and as obstructions to vision at intersections.

Control should be based on the following principles laid down in a code recently formulated by the Safety First Association of India in conjunction with the Town Planning Committee of Bombay :—

(a) *Interference.*—Billboards or advertisement hoardings in the vicinity of a highway should be located so that they will *not* affect the visibility of motorists or unduly distract their attention, especially at dangerous situations or on congested highways; obstruct the path of pedestrians or hinder their visibility at crossings; or mask the entrance of vehicles from side roads and drives into the highway.

(b) *Siting*.—No advertisement should be located within 150 feet of intersections in the country or within 75 feet of intersections in towns. The same distances apply respectively to uncontrolled railway crossings and to the inside of bends in the country or in the town.

(c) *Places of Public Interest*.—No advertisement should be located so as to obstruct or mar natural scenery, encroach upon the precincts of a historical monument, shrine or relic, or injure the amenities of any part of a neighbourhood.

Petrol and Service Stations.—While roadside advertisements and billboards are considered to be parasites of the highway, the roadside petrol and filling station, whether in an urban or rural district, is a necessity to all users of the highway. Yet, even these filling stations, if not strictly limited and controlled, often become sources of highway nuisance.

In rural districts, small filling and service stations, plastered with cheap advertising, spring up like mushrooms. Other roadside stands crowd round these regular tourist halts; and soon an ugly ribbon slum develops—an eyesore and a positive handicap to the efficiency and safety of a costly highway.

In urban areas, petrol and filling stations if wrongly sited or badly designed, not only interfere with traffic but also constitute a danger to pedestrians and a source of annoyance to the neighbourhood.

The number of fuelling and service stations should be limited. They should be set back 30 to 40 feet from the highway. They should be of a simple, straightforward pattern, designed to harmonise with the surrounding landscape. Advertisements should be limited to the name of the filling station alone.

They should be provided with proper entrances and exits. If placed on alternate sides of the road, the necessity of cutting across the traffic stream can be avoided. No pump should be within 20 feet of a street curb. They should never be located at the bottom of a steep gradient, on sharp curves, at important road intersections, or inside a bend.

In general, all filling and service stations should be kept in a tidy and orderly condition. A standard sign, signifying the presence of a filling or service station, should be fixed in advance on the highway, and no intermittent illuminated sign should be used at the station itself.

ULTIMATE WIDTH OF THE ROAD.

The design of a highway is dependent upon the maximum operating speed and the volume of traffic to be carried.

In considering the maximum operating speed of the vehicle we have to take into account the limitations of the vehicle and the limitations of the driver.

(a) *The Vehicle*.—Professor R. A. Meyer has recently challenged the practicability of an operating speed of 100 miles per hour. He points out the high cost of constructing highways suitable for such speeds. Besides, he

says, fuel costs would probably be three times as great at 100 miles per hour as at 40 miles per hour. Oil consumption at 100 miles per hour would increase rapidly, and tyre wear would probably be six times as great. Mechanical breakdowns would also increase.

It is not too much to expect that automobile designers will overcome some of the above mentioned costs of high speed and make further advance in this direction.

(b) *The Road*.—With straight, well surfaced roads having wide flanks no further improvement seems necessary ; but for all practical purposes, such conditions are not possible.

(c) *The Driver*.—There are distinct human limitations which have important relationships to driving speed. These are set out in the following table :—

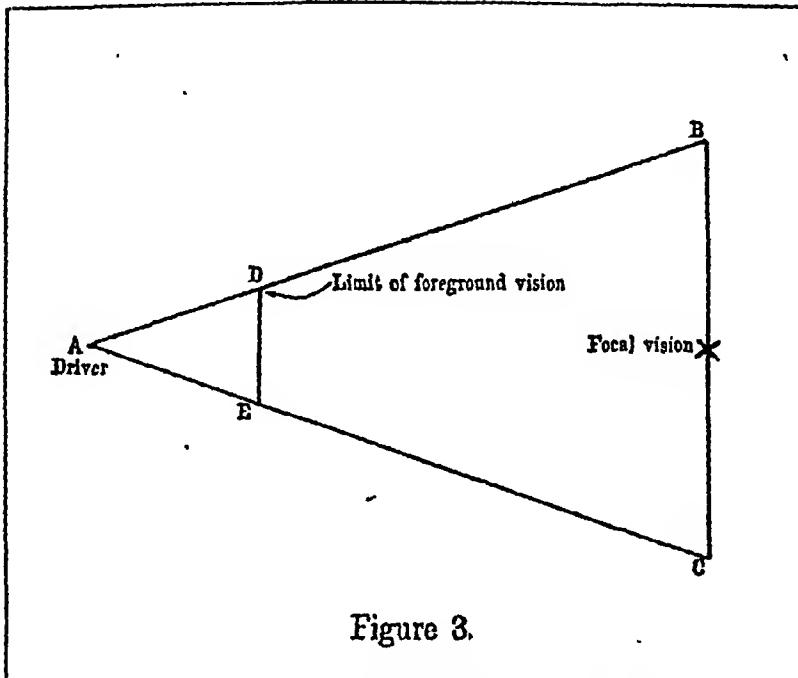
Speed miles per hour.	Foreground vision, feet.	Focal Distance of eye, feet.	Peripheral vision, degrees.	Speed in feet per second.
20	43	440	52	29.3
30	58	780	50	44
40	82	1,110	38	58.7
45	98	1,270	34	66
50	108	1,430	32	73.3
60		1,800	23	88
65		2,000	15	95.3
70		Infinity		102.7

Foreground Vision.—As the speed of driving increases, the foreground immediately in front of the car becomes more and more blurred, and the driver is not able to see clearly the details of the highway just ahead of him. Only those objects which are some distance ahead are clearly visible to the driver of a fast moving car.

Focal Point of Vision.—As the speed increases, the point upon which the driver concentrates moves farther away.

Peripheral Vision.—As the speed increases, the angle of vision narrows down from about 180 degrees when at rest to almost the width of the road when at 70 miles per hour.

The illustration (Figure 3) will make the human limitations clear :—



DE is the limit of the foreground vision.

X is the point of focal vision.

$\angle BAC$ is the angle of peripheral vision.

From an examination of the table it will be seen that the human element determines the limit of maximum safe speed for which roads should be designed, viz. 60 to 70 miles per hour.

Controlled Terrain.—In designing the highway it is also necessary to provide a right of way which is equal to the ultimate width of the road plus a strip on either side of the fast motorway for visibility purposes. While only the strip equal to the ultimate width of the road is to be purchased, a further strip, for visibility purposes, adjacent to the highway should be under the control of the Highway Authority.

The need for this strip of terrain to be controlled will be apparent when we consider the amount of time required to stop a fast moving car, which is made up as follows :—

- (a) *Perception Time.*—The time which drivers take to realise the necessity for using their brakes.
- (b) *Reaction Time.*—The time taken by drivers to use their brakes.
- (c) *Braking Time.*—The time taken by the vehicle to come to a stop.

THE HIGHWAY OF THE FUTURE.

It is suggested that the cross section of the highway needed to suit future requirements will be based upon the principle of segregating fast from slow or local traffic.

10 (m)

Where conditions are suitable, the fast and slow highways will follow the same alignment and be parallel to each other. In places they may be parallel to the railway.

The fast road will be designed on the dual carriageway principle and each carriageway will consist of two or even three lanes and a wide verge. The fast road will have a medial strip about 20 feet to 40 feet wide.

The slow or local road will be designed to carry two lanes of traffic. In towns and villages, as the need arises, provision will be made for footpaths, cycle tracks and parking strips, each separated by a verge. In towns and important villages, slow roads will be necessary on both sides of the fast road.

On this basis, the ultimate width of the road will be as follows:—Fast road 140 feet; slow road 80 feet. Such roads would be constructed in stages.

Where both roads are in parallel alignment, they would have to be separated by a strip of land—40 feet is suggested.

It will also be necessary to control, for visibility purposes, the use of the land on either side of the fast roads—30 feet strips are suggested.

The factors in this problem are as yet imperfectly understood and an investigation is being made in this connection.

In towns and important villages, the right-of-way to be purchased will equal:—

Fast Road	...	...	140 feet.
2 Slow Roads @ 80 feet	...	...	160 „
2 Dividing Strips @ 40 feet	...	...	80 „
			<hr/> 380 „ <hr/>

Whilst the width of the strip to be controlled will be:—

Ultimate right-of-way	...	...	380 feet.
2 Visibility Strips @ 30 feet	...	...	60 „
			<hr/> 440 „ <hr/>

This forecast of the probable cross section of the future highway may seem to some to be fantastic. But let them not forget that what we take as matters of fact today seemed equally fantastic to the generation before us. The Speed King of half a century ago would appear like a slow motion acrobat if he took the road with Malcolm Campbell today. It was a general belief, then, that travelling over 100 miles per hour would kill a man, even granting that such an impossible speed could be attained.

The highway that is constructed today must be constructed to satisfy the need of the future, and not merely to quiet the demands of the present. What have our Highway Authorities done in this direction? For all practical purposes, they have not even begun to think over the problem. Our Town Planning Commissions too are acting as though there was no need whatsoever to adapt our roads and highways to anticipate these future conditions.

The motor car, for instance, ought to have been anticipated at the beginning of the century. It was bound to come; yet only Haussmann in Paris had the foresight to plan out a city for the needs of future transport. In other countries nothing was done to meet the inevitable consequences of motor transport. Highway Authorities let consequence after consequence take them by surprise, and then tried their remedies—belatedly.

The same fate is in store for our cities and trunk highways unless something is done and done immediately—soon, it may be too late.

WHAT OTHER COUNTRIES HAVE DONE.

The English Restriction of Ribbon Development Act.—The English Restriction of Ribbon Development Act of 1935 has three main objects:—

The control of access to roads.

The control of the use of the terrain adjacent to the road for the purposes of visibility and the prevention of distraction.

The provision of parking facilities.

1. By access is understood the construction of pathways or carriage-ways leading to the road, or the insertion of a gate or stile in a fence along the road.

The Act makes it unlawful, without the consent of the Highway Authorities, to construct any means of access to all classified roads, to certain unclassified roads mentioned by the Highway Authorities, and to all proposed roads.

2. By control of the use of the terrain adjacent to the road is meant the prevention of the erection of buildings alongside the road which may hinder motorists' visibility, and the prohibition of roadside advertisements which affect motorists' visibility, cause distraction to the motorist, or mar the beauty of the countryside.

In the case of existing roads it becomes unlawful, by this Act, to erect any building within 220 feet of the middle of the road.

In the case of proposed road the Highway Authorities may compulsorily acquire land within 220 feet of the proposed road in order to prevent the erection of buildings which will hinder the view of the motorist.

If the Highway Authorities do not exercise the power to acquire the adjacent terrain, then it is permissible for adjoining property owners to build up to the ultimate width of the road. The ultimate width is the width that is fixed by the Highway Authority for any particular road (60 feet to 160 feet). In many cases it may happen that the actual width of the constructed road is less than the width fixed by the Highway Authority for that road—the width fixed is the ultimate width.

Note.—In all cases compensation shall be paid to any owner who can prove that his estate or interest is injuriously affected by the restrictions imposed on his land by this Act. The land can be said to be injuriously affected when its development is prevented by this Act, if the development is practicable and if there is demand for such development.

3. Provision is made for parking facilities by extending the powers of Local Authorities, who are given the power to maintain buildings for use as parking places and to acquire land for the purpose of providing means of access to such buildings.

Local Authorities are also given the power to demand the provision of adequate parking accommodation for all proposed buildings of 2,50,000 cubic feet and upwards, for petrol filling stations, refreshment houses, or stations for Public Service Vehicles.

U. S. A. Highway Zoning.—Different methods are adopted in controlling and regulating roadside uses in different countries. In America, many States favour the new method of highway control—Highway Zoning.

Highway Zoning is the most practical method of securing roadside control, for it provides for the general control of the entire length of highway terrain by State regulation and also for the particular control of sections or districts along the highway (which may need differences in regulation) by local restrictions imposed by the Highway Authorities.

The term Highway Zoning would thus include both linear zoning as well as district zoning. By linear zone is meant a strip of X feet of adjacent terrain on each side of the entire highway which is subject to the general restrictions as to land use imposed by the State. Besides these general restrictions, the Highway Authorities are given power to regulate and control the adjacent terrain according to the particular needs of the locality through which the highway passes.

In practice, 'zoning' deals largely with land uses, but not necessarily so. Thus, for example, the Highway Authority may make different regulations as to the height of buildings, setbacks from the building line, etc., to suit the requirements of different localities which front on the highway. For instance, the Highway Authorities may stipulate a setback of 100 feet in one district and only 70 feet in another; but no permission can be granted even by the Highway Authorities for a location within 50 feet of the right-of-way—this being a general restriction placed along the entire length of terrain by State regulation, according to the principle of linear zoning.

Again, the Highway Authorities may regulate the use of land fronting on a highway, for business or residential purposes.

In district zoning, the entire length of the terrain adjacent to the highway, extending for miles, would be divided into zones or districts, each allocated for special purposes. The zoning plan usually provides for four main classes of districts :—

- (a) *The Residence District* where only residences and accessory buildings can be erected.
- (b) *The Business District* where only stores, with a minimum of light manufacturing as accessory, can be built.
- (c) *The Industrial District* where buildings for any industrial activity, except heavy and nuisance industries, may be erected.
- (d) *The Rural District* where the land fronting the highway is mostly devoted to farming or plantations—including the sale thereon of their own products; parks, recreation grounds and reserves; cemeteries, schools, churches and a limited number of residences.

The determination of the boundaries of these districts shall be left to the judgment of the Highway Commission.

Advantages.—The system of "Highway Zoning" adopted in America to control and regulate roadside uses has two important advantages over the "Restriction of Ribbon Development Act of 1935" passed in England for the same purpose :—

1. The varying of restrictions to suit the requirements of particular localities which Highway Zoning allows, gives to zoning a distinct advantage over the English method of uniform restrictions imposed along the whole length of the highway. Zoning exercises a uniform general control through linear zoning, and also provides for adaptation of special restrictions to suit particular localities by district zoning.

2. The application of the principle of zoning to any highway does not entail payment of compensation to property owners of the adjacent terrain. Zoning is done under what in the United States is called Police power, and consequently property owners have no right of damage for restrictions on their use of property. In other words property owners are free to make any use of their land provided they do not cause nuisance to the community in general; and any use of land will constitute a nuisance which adversely affects the protection of life, the health, the morals, or the general welfare of the community—the Municipality or zoning authority being the sole judge in this matter.

Neither the restrictions nor the refusal to pay compensation for alleged damages sustained by the restrictions are in any way unfair or unjust. Property owners, usually well paid for the right-of-way land which they sold to the Highway Authorities, seek a second reward through use or sale of frontage property for roadside stands, petrol stations, billboard sites and other similar uses. This ultimately destroys both the attractiveness and the efficiency of a highway constructed by public investment. This is often the fate of a costly highway, simply because the Highway Authorities failed to exercise reasonable control of highway frontage development and use.

BYE-PASS ROADS.

When there is heavy through traffic between two centres, it is not fair to make that traffic force its way through intermediate communities, as this :—

- (a) Crowds the local streets with non-business bringing traffic ;
- (b) Decreases the attractiveness of the local business centres ;
- (c) Adds to the local tax-payers burden on account of increased road repairs and traffic control ;
- (d) Subjects the local people to unnecessary hazards of life and limb, to noise, dust and dirt, and to pollution of the atmosphere occasioned by motor vehicle fumes.

Principles to be observed in the layout of Bye-Pass Roads.—1. Prohibition of building on either side of the road for a distance of X feet must apply before the road is built, i.e., there must be a Ribbon Development Act,

or, alternatively, the land must be bought by the Highway Authorities, or the use of the land must be controlled, *i.e.* it must remain a bye-pass and not a new street.

2. The take-off, *i.e.* the entrance and exit should be easy.
3. Should be as direct as possible.
4. Should be built for a reasonably high safe speed.
5. Access to the bye-pass road should be denied, *i.e.* no cross roads or entrances.
6. Visibility, both vertical and horizontal, should be 100 per cent, *i.e.* no blind corners or restricted views.
7. Use of the bye-pass should be restricted to fast motor vehicles only.

Benefits of Bye-Passing.—1. So far as the tax-payer is concerned, bye-passes are preferable and more economical than widening a heavily-trafficked business street, provided Ribbon Development is prohibited.

2. So far as the resident is concerned, congestion, danger of accidents, noise, smell and pollution of the atmosphere is minimised. Local business and traffic is not interfered with. Residential property is thus protected.

3. So far as the through passenger or driver is concerned, traffic congestion is relieved. Accidents are lessened and traffic is enabled to attain reasonable speed.

SERVICE ROADS.

In built up or residential areas, private carriageways with entrances or garage entrances, etc., seriously interfere with the passing through traffic, whilst cars parked along the road reduce the effective width of the carriageway and therefore obstruct the passing through traffic.

When new roads are built, such interference and obstruction can be prevented by the provision of a separate service road laid parallel to the main highway for the purpose of accommodating local traffic.

The principles to be observed in the layout of service roads are:—

1. Access to main roads should be kept to a minimum. In towns, cross roads should generally not be spaced less than 440 yards apart.
2. The carriageway of the service road should be sufficient for two streams of slow moving vehicles, *i.e.* a minimum of 20 feet—26 feet is better.
3. A foot-path, to accommodate foot traffic and the utilities, should be provided.
4. Separate cycle tracks—minimum of 6 feet—are desirable on both sides of the carriageway.
5. The buildings abutting should have sufficient space within the compounds to accommodate the vehicles of residents, visitors and tradesmen; where this is not possible a parking strip of 8 feet width should be provided.
6. Verges separating the footpath, the cycle track and the carriageway should be provided—6 feet is suggested.

7. Corner development should be controlled to aid visibility, and kerbs of a minimum radius of 30 feet should be used.

GROUP DEVELOPMENT.

Group development should be encouraged by local authorities, by planning in advance the development of areas away from arterial roads. This plan should necessarily form part of a master plan.

If streets and utilities are provided well in advance of building requirements—in suitable areas—then such areas will attract buyers.

Villages and their Relation to Main Roads.—The development of villages and towns along main thoroughfares is wrong in principle and should be avoided. Planned development should take its place. The main road is an unsuitable situation for a town or village.

Replanning of Existing Villages.—The question is what is to be done with existing villages through which main roads go.

The remedies suggested are :—

- (a) Bye-passing the village.
- (b) Widening the main road and adding service roads on both sides to deal with the local traffic.
- (c) Replanning the village away from the road and taking advantage of rebuilding, expiration of leases, etc., to rebuild the village away from the main road in accordance with the principles set out under "Siting of New Villages."

The question of bye-passing and service roads has been dealt with before.

Rebuilding of a village away from the main road is not such a difficult matter as it may seem. The thing can be done by a bold use of the blessed gospel of opportunism by the inevitability of gradualness. It means the seizing of the apparently small opportunities that occur as rebuilding takes place, and as leases expire; and from the continued seizing of these opportunities, the gradual realisation of a scheme that may have occupied years between its inauguration and completion. There has been an immense amount of rebuilding in the central areas of our large towns during the last decade and there has been a lamentable missing of the opportunities that this rebuilding has afforded.

"The most inspiring and almost the sole example of rationalised opportunism in town improvements is the street system in Paris. There two or three centuries ago Haussmann and his associates designed a scheme for a complete replanning which has been steadily realised from that day to this. The imagination and courage shown in designing and executing that scheme, long before the advent of motor transport, was stupendous. And the result is magnificent." [Thomas Sharp—"Town & Countryside"].

If a complicated city like Paris can be replanned, how easy it would be to change the site of a village from the main road to a better site off the main road where the villager can enjoy the health and pleasure which is denied to him when he lives on the main road.

Siting of New Villages.—The principles to be observed in the siting of new villages and re-development of older villages are as follows :—

1. The site should be sufficiently far away from the main road to admit of the drivers of fast traffic seeing in good time any traffic emerging from the village road.

The terrain within the triangle of visibility (*viz.* A.B.C. in figure 3, drawn for 70 miles per hour) should be free from buildings, trees, hedges or other obstructions, and the use of the terrain parallel to the road should be controlled for a width at least equal to BC as shown in that figure.

2. Access to the main road should be limited. Where there are several villages, they should, as far as possible, be connected up to the same road.

3. The intersection of the village road and main road should be at right angles as far as possible.

4. All cross traffic should be made to stop before entering the main road. A gate which would operate traffic signals would be an advantage.

5. The buildings should be built of local material.

6. The site should be chosen with regard to landscape, water, prevailing breeze and drainage.

FINANCE.

The all important question of finance will deter the majority from proceeding with the solution to the problem. They will prefer to muddle through without a plan, then find it necessary later on to undertake widening and other road improvement schemes at a cost which will be considerably greater than it would have been if tackled on a planned basis.

The question of finance determines whether there should be :—

- (1) Restriction of Ribbon Development, or
- (2) Highway Zoning.

The motorist is already contributing heavily to both Central and Provincial Governments, and Municipalities and Local Authorities.

In England, the cost of financing the restriction of Ribbon Development is met by the Road Fund and it is suggested that the same procedure be followed here.

WHAT SHOULD BE DONE IN INDIA.

Control is desirable over all highways. However, in a vast country like India, with limited finance, the cost of giving effect to this would be greater than the capacity to bear. But we must have the necessary legislative machinery and this must be exercised at important points at least.

They can be summarised thus :—

1. All approaches to towns and large villages along main roads should be controlled.
2. The use of the terrain on both sides of new trunk roads should be controlled.
3. Advertisements and Service Stations along all highways should be limited and controlled.

4. The terrain on both sides of bye-pass roads should be controlled.
5. The corners of all intersections with main roads should be controlled.
6. *Anywhere* along the main highway where symptoms are evident of the building of a town or large village, such as may be occasioned by the discovery of metal ore or the location of medicinal springs control should be exercised.

Control should extend over 440 feet, *i.e.*, 220 feet on either side of the centre line of the highway.

As to the choice of method of control, the author is of opinion that the Zoning method is preferable. Its advantages have been discussed before. It will considerably lessen the financial difficulty.

The proper time to introduce legislation to control Ribbon Development is now.

There are many considerations which make it imperative that legislation should come to the rescue of the highway authorities.

The tourist business has become a leading industry in many countries; and India can take the first place if only facilities for tourists are forthcoming. What country can match with India in the lure of her unconquered snow-peaks, the charm of her quaint customs, the glory of her historical monuments and the mystery of her religious ceremonies? All these are hidden from the thousands of tourists who regularly visit other countries, because it is well known that touring in India at present is anything but a pleasure.

It is also in the interests of industry that highway control and development should be taken in hand immediately. No one will deny that the project needs money; but only the blind can fail to perceive that the returns will repay the outlay.

The people of India are principally agriculturists—they belong to the land. They are happier in rural surroundings. But a well-planned system of roads is necessary to enable them to sell profitably their agricultural and cottage industry products. Cheap transport, quick routes and minimum handling are necessary for this. Only then can the ideal of modern planning be attained, where the people can live as near to the countryside as possible. If transport is facilitated, inland produce can find a ready market. If transport is cheap and quick, cottage industries will flourish. If transport is easy, heavy industries can work unrestricted far away from towns and congested areas.

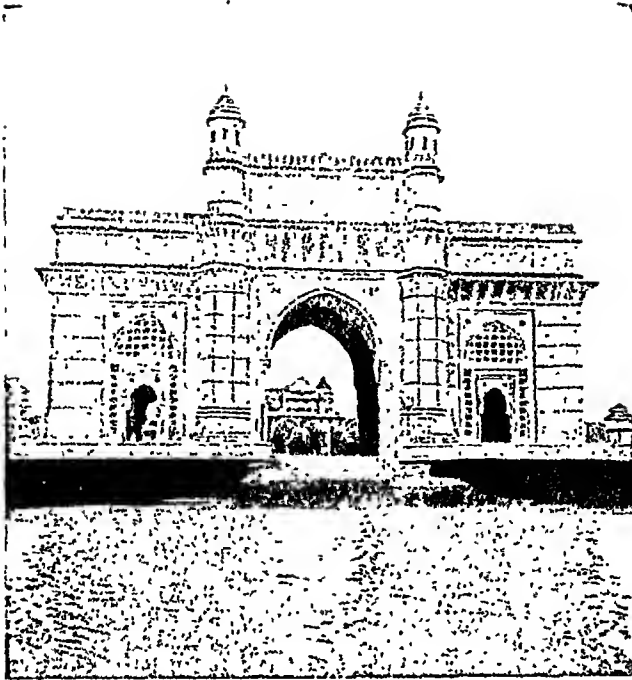
Cheap road transport is necessary for the progress of trade and commerce. Transport facilities create business and larger profits for the farmer and the internal producer.

But mere development and control of the highway is not enough. Random development, piecemeal control, and ill-conceived planning will lead to nothing good. We must plan with foresight, and then build in accordance with the preconceived plan. We must have Regional Plans, drawn up for every region or district, and Master Plans prepared for every one of our towns. The alignment of the road should be designed to satisfy all requirements, and all safety measures should be considered. Every detail must be worked out in view of the ultimate and preconceived plan; nothing should be left to chance, whim or caprice. The foresight of Haussmann must inspire us.

After foresight comes courage. What India needs most today is men of foresight and courage. Foresight to deal with the problems that are bound to come, and courage to face the opposition of those who would live for the present and let the future take care of itself.

The Present is what the Past planned out; the Future will be what the Present conceives. What is the legacy that we wish to leave behind us?

Admiring a beautiful Italian city, Huxley said: "I thought of all the men who had lived here and left the visible traces of their spirit and conceived extraordinary things." Is that the legacy we wish to leave behind?



No. 1 The Gateway of India.
Sea approach to Bombay.



No. 2 Land approach to Bombay.
Bottleneck on Bombay-Agra Road.



**No. 3 Land approach to Bombay.
Ribbon Development along the Ghod Bunder Road.**



**No. 4 Land approach to Bombay.
Junk yard along Ghod Bunder Road.**

DISCUSSIONS ON PAPER No. M.

Lt.-Col. H. C. Smith (Bombay):—In the absence of the Author, Mr. Ormerod had agreed to introduce this paper, but I regret to say that he is suffering from an infection of the throat and you will be deprived of hearing that well-known voice at this Congress. I have, therefore, been asked to introduce the paper. Before doing so, let me say how sorry Mr. Trollip is that he is not able to be here.

You will remember that the original dates for the Congress were fixed for 5th to 12th, and on this Mr. Trollip arranged to give his presidential address to the Association of Mechanical Engineers on February 17. Then came the change of dates and Mr. Trollip has found it impossible to alter his programme.

Since the date when the paper was written, Mr. Trollip has made a further study of the subject and has drawn up a list of alterations and additions which I will pass on to the Secretary for inclusion in the final proceedings.*

In every country in the world, the development of motor vehicle transport is creating new and difficult problems. Ribbon development is one of these. England has tackled the question by passing the "Restriction of Ribbon Development Act" and the United States has done the same with the "Highway Zoning Act". In India, nothing has been done as yet to forestall or combat the evil, but it is understood that steps are now being taken to restrict Ribbon Development and to safeguard Provincial roads in the Bombay Province. In future, it is said, no villages will be permitted to spring up close to Provincial roads; and where these Provincial roads are being developed (as in the case of the Bombay-Poona and Bombay-Nasik Roads), bye-passes are to be constructed wherever possible.

Rigid control of the highway and the adjoining property is essential if road transport is to progress in India as it has done in other countries. The legislative means of achieving this should be examined; and if the existing machinery is insufficient for the purpose of adequate protection, special measures should be passed without further delay so as to make ribbon development impossible.

The main purpose of the restriction of ribbon development (1) is to limit access to the highway so as to facilitate through traffic (2) is to prevent physical structures i.e. buildings, bill boards, etc. from being erected within a certain minimum distance of the highway in order to ensure good visibility for driving, and (3) is to enable future road widenings to be made at the minimum expense.

If ribbon development is not restricted, roads become more and more crowded with local traffic and through traffic is seriously handicapped. This makes for traffic congestion and accidents. The exits to a large town must be ample. A few direct bomb hits on these could hamper evacuation and hinder traffic enormously. Where bye-pass roads are constructed for the

* These appear on the page facing the first page of paper M.

express purpose of facilitating through traffic, new buildings spring up alongside if control is not exercised; the purpose for which the arterial or bye-pass road was constructed, is thereby frustrated as through traffic is hindered by local traffic, and by obstructed visibility. This results in sheer waste of public money spent in building a costly highway.

Existing Measures of Control:—The question of controlling unsystematic building over large areas in suburban localities, I am told, has been engaging the attention of the Government of Bombay. There are possibilities of the "English Town and Country Town Planning Act of 1932" being adopted here. This, of course, involves the question of compensation, and the participation of Local Authorities in the planning, and partial financing of such schemes, and it is unlikely that the adoption will prove successful.

Under the Rayatwari tenure, which controls the use of the land in the Province of Bombay, the Collector has the power to refuse, subject to the general orders laid down by Government, the conversion of land from agricultural to non-agricultural use. Collectors may refuse permission to convert land to non-agricultural use under certain conditions, sanitary, civic and æsthetic matters being taken into consideration, but at the present moment Collectors are reminded that such refusals should be exceptions rather than rules. It would, of course, be possible for Government to pass general rules restricting the use of land along highways; but so far Government have not laid down any fixed policy in that matter. Ribbon Development must be restricted by a Special Act, and until such legislation is in force, general orders should be issued to Collectors not to allow non-agricultural use of land within 220 yards of a main highway.

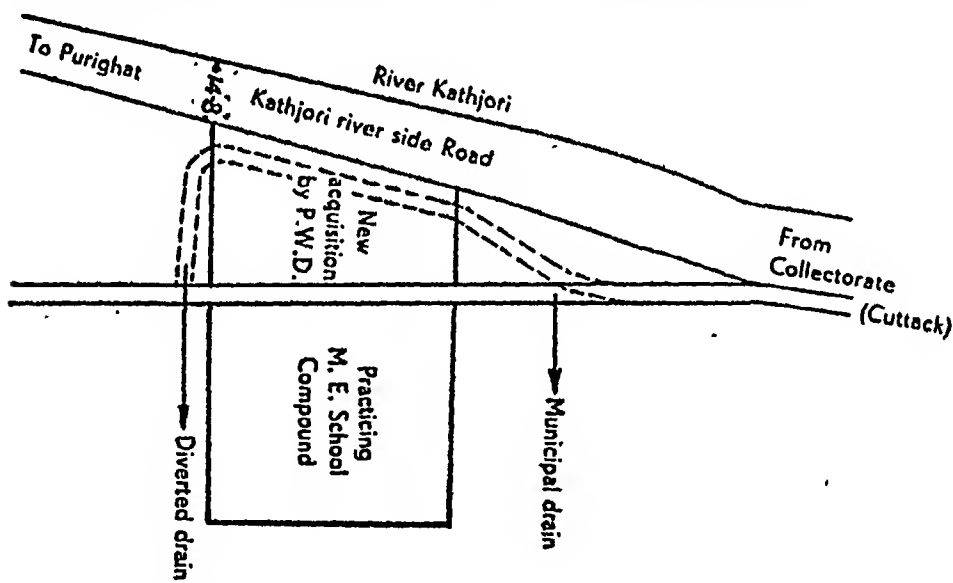
The systems followed by England and America for the restriction of Ribbon Development have been outlined by Mr. Trollip in this paper and their advantages and disadvantages briefly dealt with. The question of finance and compensation to property owners has also been considered. The urgent need for legislation in this matter must be made clear. The paper has been prepared with a view to throw more light on this important problem and to urge that legislation should be enacted now while there is still time to prevent what may soon become financially difficult at a later date.

I have much pleasure in introducing Mr. Trollip's paper.

Mr. M. Mahapatra (Orissa):—All of us know the evil effects of Ribbon Development. The author has very clearly stated the cause and has made definite suggestions to solve the problem. We find the same people, while living in villages, build their houses in regular lines with straight roads in the front and spacious yards on the back, but when they come to a town they want to utilise the very inch of land they possess in erecting structures, without having any consideration for ventilation and drainage. The reason is that in villages the land is very cheap while in towns each inch of land means money.

I had an opportunity to be in charge of Municipal work and had bitter experience of ribbon development. What to speak of leaving frontage and side space, the public land was gradually being encroached upon by extending

foundation projection, construction of steps over side drain, projection of platforms, sunshades and balconies. These projections are not mere encroachments. They further reduce the traffic way by a few feet to accommodate electric lines which cannot be within an easy reach (that is as far as I remember 2 feet 6 inches) from any part of a building. The Electric Supply Company, being a business concern, find the line of least expense for their transmission lines. They submit a plan which is approved by the Municipal authorities. While approving such plans if proper care is not taken the transmission line posts become obstructions at junctions which cannot be easily shifted afterwards. Not only The Electric Supply Company, but others also, even the Public Works Department take advantage of the slackness of the Municipal authorities and get their respective ends fulfilled without considering how the town and the town people are going to be affected. I may be excused to mention an instance in which the Public Works Department wanted to divert a deep Municipal drain to the edge of a hazy narrow road in order to utilise a newly acquired piece of land located between the drain and the road, as a part of the compound of a school on the other side of the drain. As per the first proposal, the six feet deep drain was coming to the edge of the road which was 14 feet wide. With great difficulty the approved plan was modified and the Public Works Department left a strip of land 6 feet wide between the Municipal road and the proposed diversion.



So many similar cases come to the notice of the Municipal Engineer that if he is not very particular about his duties and is yielding to the will of the Municipal Authorities who are the influential people of the town, owners of urban land and buildings, it is very difficult to carry on any improvement or to check congestion and insanitation.

In accordance with the Municipal Act and By-laws, no new structures can be erected, old structures remodelled, and new roads laid, without the written approval of the Municipal Authorities. If the mind to improve is there, much can be done, step by step, as a part of the future town-planning. But as any improvement, at first, seems to affect the interests of the people

in power, though the idea of improvement may be there in the mind of the Engineer, he cannot do much in that direction. The pity is that there is no Governmental control on these matters either through the agency of the Public Works Department or the Public Health Department. The Director of Public Health holds annual inspection and, generally, gives his remarks on the medical branch of the Municipality. Rarely does any officer suggest further development of a growing town. In consequence, old part of the town gets more and more congested and anybody wishing to go out of the town disturbances has to build a house on a newly acquired piece of land with no roads or means of drainage. Municipality goes on permitting structures one by one without any definite plan in view. One case I would like to mention, and that is, up to 1936 a portion of the South-Eastern part of Cuttack was subjected to stagnation of water during floods. On shifting the sluice of the main drainage to 7 miles below, the side lands are now properly drained, and the town is extending in that direction. In 1936, I anticipated this and proposed that a proper survey be made and the line of roads and drainage, etc. be laid on a plan which will be the guide for town-planning. It was also suggested that the existing buildings and tanks of the old town be shown on the plan with improvements proposed to be effected in future, and as soon as an old building is dismantled the new one will be constructed to fit the future improvements. But due to financial difficulty the proposals could not mature. Cost of the waste land on the side of drain was Rs. 100/- per acre in 1936. The price has gone up to Rs. 1000/- per acre and there is a chance of further rise. I find buildings are being constructed without any plan of roads and drainage. We cannot expect any improvement if such things continue.

As suggested by the author, at page 16 (m), if the Road Fund finances the restriction of Ribbon Development, the condition may improve. Further, I would suggest that town-planning should be under the control of the Chief Engineer of the Province who will hold regular inspections and examine the developments and suggest further extensions. The Municipality, before contemplating to increase their residential area, should prepare a plan of the proposed lines of roads and residential blocks, and submit it to the Chief Engineer for examination and approval. It is necessary that regulation be laid down by this Congress for town roads, and means devised to see that they are carried out.

Mr. Syed Arifuddin (Hyderabad-Deccan):—In connection with corner visibility, Mr. Trollip has dealt with a case of 4 roads only where the angle is a right angle. The junction of 3, 5 and 6 roads, and the safest ways of controlling the traffic at these junctions, also need consideration. The face of the junction of greater number of roads than 6 is a rare one. At such junctions there are points of divergence, convergence and intersection of traffic. There are as many points of divergence and points of convergence as the number of roads at the junction; but the points of intersection or collision increase enormously with the increase in the number of roads. To determine the number of collision points I have derived the following formula. If n be the number of roads at the junction and Y the points of intersection.

$$Y = n[1(n-2) + 2(n-3) + 3(n-4) + 4(n-5) + 5(n-6) + 6(n-7) + 7(n-8) + 8(n-9) + 9(n-10) \text{ etc. etc.}]$$

to $(n-2)$ terms

$$\text{If } n=10, Y = 10(1 \times 8 + 2 \times 7 + 3 \times 6 + 4 \times 5 + 5 \times 4 + 6 \times 3 + 7 \times 2 + 8 \times 1) = 1200.$$

25 (m)

The number of points of collision at the junction of several roads as worked out by the above formula, which can be checked by drawing the lines, if desired, are given below :—

No. of roads.	No. of points of collision.
3	3
4	16
5	50
6	120
7	235
8	448
9	756
10	1200

It will be evident how enormously the chances of collision increase with slight increase in the number of roads. It is for this reason that gyroscopic movement of traffic is now enforced at junctions with the restriction of speed. On fast traffic highways where such restriction is not considered advisable, crossings are provided above or below the highways so that the highway traffic is not interfered with on any way. For such highways, there are two lines of traffic each way for automobiles, one of it being for overtaking the cars in front at some places there are altogether 3 lines of traffic, the middle one being for the purpose of overtaking. The later is not so safe as the former.

Where the circular movement of traffic is enforced, it is essential to have a circular obstruction in the middle as is often done now-a-days. The diameter of the circle depends on the permissible speed, the number of roads, the width of the roads, and also the radii of the curves at the corners.

There are two ways of determining the diameter of the circle. The figure 1, page 26 (m), explains one method and the figure 2, page 27 (m), the other method. In the first method, points of collision are not completely avoided; they will be reduced to the number of roads which is a great point. For instance in the case of 4 roads they will be reduced from 16 to 4, and in the case of 10 roads from 1200 to 10. In the later case, they are completely avoided.

I would therefore recommend that these points may also be included in the Draft Code and suitable recommendations may be incorporated in it for the following dimensions:—

1. Dimensions of the circle in relation to the width of the road—minimum and maximum.
2. Radius of the curves at the corners—minimum and maximum.
3. Maximum speed at crossings where suitable circles are formed and where they are not.
4. Length of the adjacent sides of the Triangle of Visibility for different included angles.

FIG. 1.

SCALE 1" = 50 FEET

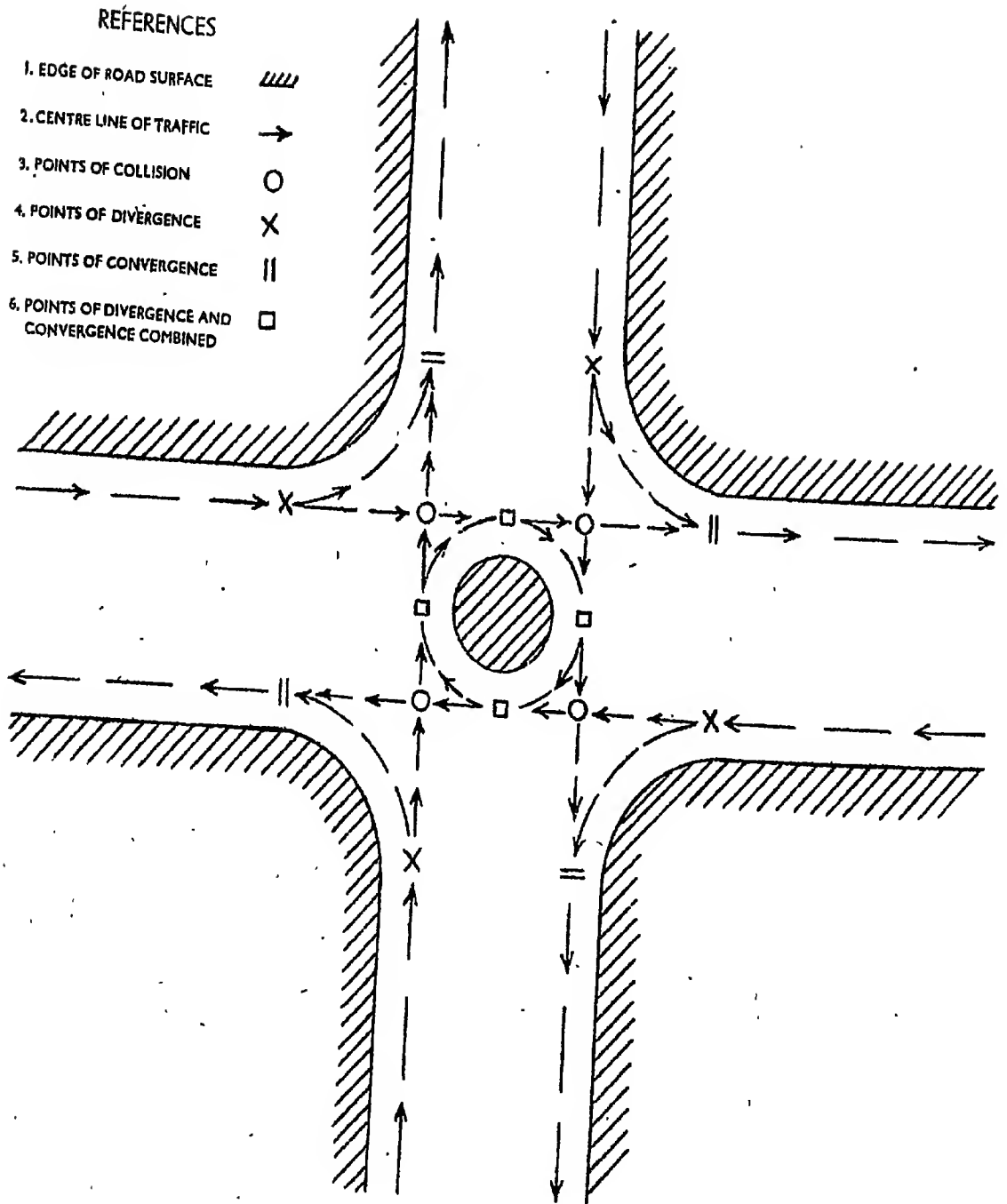
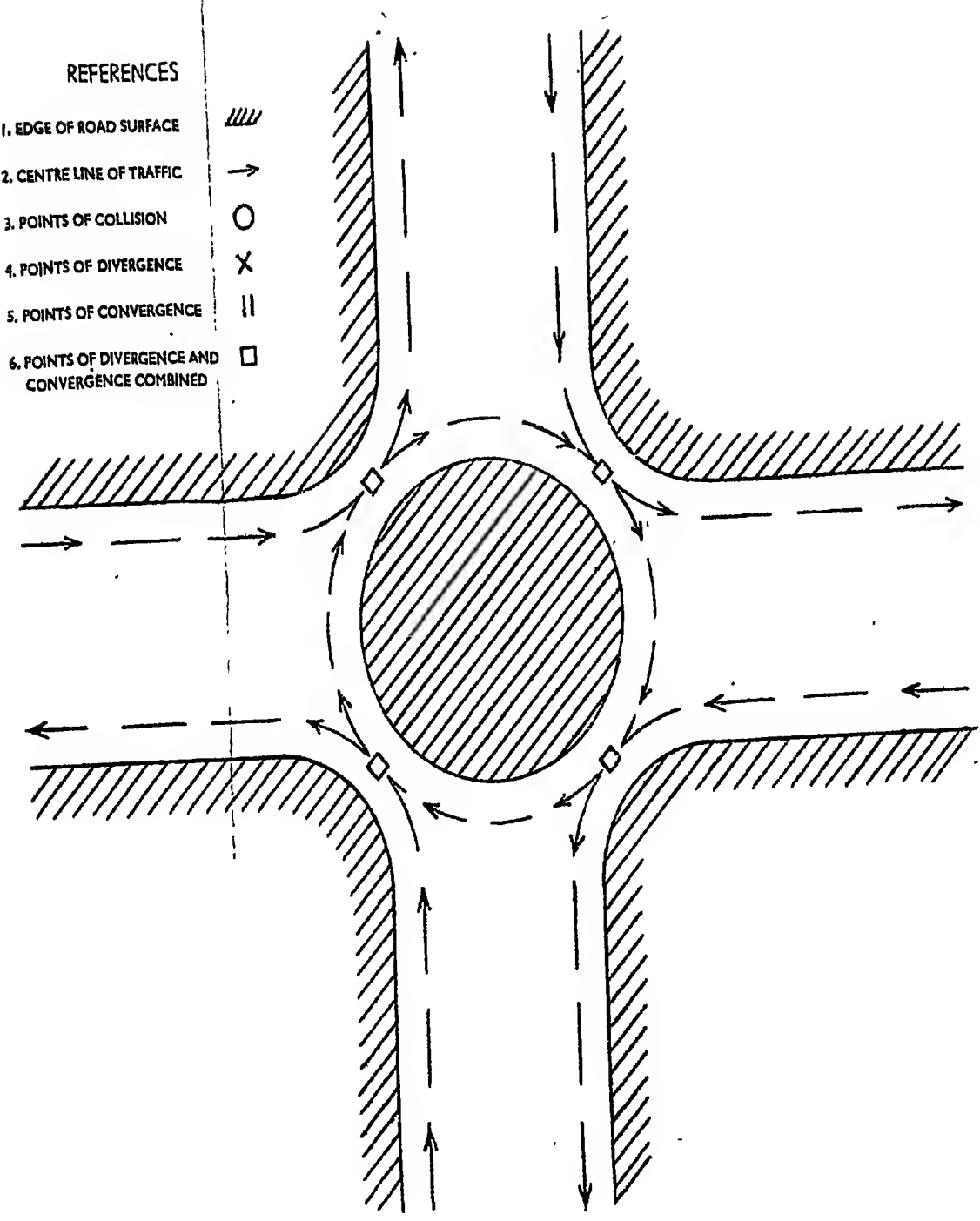


FIG. 2.

SCALE 1" = 50 FEET



Mr. S. Bashiram (Punjab):—I rise to emphasize that the importance of Mr. Trollip's Paper is not so very remote as some may be inclined to imagine. Things in this direction in the Punjab are getting very serious indeed, and we find that this sort of Ribbon Development is proceeding apace along existing roads, not only in the neighbourhood of large towns but also along small road-side villages which, later on, develop into big *bustees*. Owners of properties abutting on the road-land build just a few shops, etc. and, thereafter, use one-third or more of the roadland as their private property for stacking their material and merchandise. Sometimes they use this land as their private preserve for sitting out and even planting a shrubby garden. For example, to give you a specific instance, we have the case of a town in Ludhiana District. Our roadland there is 200 feet wide, 100 feet on each side of the centre line. Conditions there have become so dangerous that there is a constant danger of accidents. The roadland immediately in front of the shops and to a depth of 50 to 60 feet is absolutely covered over with stacks of grain and then comes another depth of 30 to 40 feet full of bullock-carts which bring the grain to this market. Hawkers squat on the balance of the road width including the berms.

It is absolutely essential, therefore, that some sort of building line be fixed and such a line should be at a reasonable distance from the boundary of the roadland. If the above mischief is to be avoided, there must be some unbuild area between the road boundary and the building line.

The question arises as to what is a highway? The highway law in India is in a very chaotic condition. On reference being made to the Legal Remembrancer in the Punjab it was opined that property owners along a road have got unrestricted right of approach to all parts of their property from all parts of the highway. It may thus be argued that the construction of even a petrol pump on the roadland is an obstruction of such a right and is, therefore, illegal.

Rai Sahib Fateh Chand (United Provinces): According to the Municipal Act, it is illegal.

Mr. S. Bashiram (Punjab):—It is absolutely essential, therefore, that some very early means must be found to check this nuisance and it is very desirable that any action taken should, if possible, be on all India lines.

Mr. K. G. Mitchell (Government of India):—I think we ought to be grateful to Mr. Trollip for introducing this subject to us. Ribbon Development is going to be a great problem. I would only say one thing. Mr. Bashiram said that the matter should be tackled urgently and as an all-India question and not a Provincial one. Of course, as you know, if any legislation is required, it must under the Constitution be Provincial legislation. Roads are subject to Provincial legislation and, therefore, this Congress can only make recommendations. It must be for the Provinces themselves to legislate.

Mr. R. A. Fitzherbert (Bombay):—On page 2 (m) of this paper, below paragraph 4, the question of control of road territory and Ribbon Development is mentioned. This development cannot really be much controlled until we have the necessary legislation, but meanwhile we can adopt various remedies to restrict development.

One of the problems we are up against as regards control of Ribbon Development in the Bombay Presidency, and, I believe, in the Punjab, is the question of road boundaries, and it is very necessary that Governments should take up this question seriously and without delay. As things are now, when the question of a road boundary crops up, we go to the Revenue Authorities and say "Here is our boundary" and the private land owners concerned say "No, this is the boundary", and then the Public Works Department says "That boundary stone was moved three years ago" and so-on.

It seems to me very important to impress on Governments, so far as we can, the necessity for early revision of all road boundaries.

Another item of control is as regards advertising. Bombay itself has some bad examples of the lack of control in this matter.

You will see enormous advertisement signs such as "Players Please" and large posters close to small road direction signs which are hardly noticeable.

A third item where control is needed is in the location of petrol stations.

It may be a hardship for the Petrol Company to be obliged to purchase or lease more land than they need, but if a petrol pump is located at or near a corner, I always stipulate that the pump must be at a distance one and a half times the length of a motor lorry from the corner. This is to avoid congestion of traffic.

Something of this sort is necessary if Ribbon Development is to be checked.

Then there is another way in which control can be exercised.

In the Bombay Presidency, Revenue Commissioners can forbid all buildings along extra-municipal roads within 10 feet of the road boundary. I do not know if this is the case in other Provinces.

Again I would say that the question of road boundaries is of very great importance.

Mr. R. Trevor-Jones (Punjab):—On page 11 (m) of Mr. Trollip's paper it is stated "Highway Authorities let consequence after consequence take them by surprise, and then tried their remedies belatedly."

We may ask ourselves why? One of the main reasons, as far as we are concerned in the Punjab, is that we have no legislation at all except the local Motor Vehicles Act. I believe certain Provinces have Highway Acts, but I do not know how many. (A voice "Mysore is one"). I do not know whether it would be possible for this body to state authoritatively that it is very necessary that each Province should have its own Highway Act. This is realised locally to some extent, for not long ago, the Public Works

Department were asked if they could quote any legal authority for working on and maintaining the roads in the Province, and as far as I know, the answer was in the negative.

Lt.-Col. H. C. Smith (Bombay):—I do not feel confident to answer all the points raised by members on Mr. Trollip's paper. I imagine that the author in due course will give the necessary reply and his reply would appear in the Proceedings.

CORRESPONDENCE.

Reply received by post from Mr. A. S. Trollip (Author) to the discussions on Paper No. M:—

I am glad to observe that all the Engineers who so kindly took part in the discussion agree with the need for controlling Ribbon Development. It is a very urgent subject and is one which some local organisation in every Province should make their pet hobby to hammer at. Since reading this Paper, the Bombay Joint Town Planning Committee have formulated a programme and will be raising this question in the Bombay Legislative Assembly. In the meantime means are being taken to prepare propaganda against Ribbon Development.

Government have powers under Section 45 of the Land Revenue Code to prevent the transfer of land from agricultural to non-agricultural use. If Government issue orders to Collectors and Officers concerned to prevent this, Ribbon Development could quite easily be stopped. There is no reason why people should be compensated for restrictions placed on their land, since they have already been adequately paid for the width of terrain on which the road is accommodated.

In reply to Mr. Syed Arifuddin's proposals, the formula which he suggests can be condensed into the following simple form:

$$Y = \frac{1}{2}n^2(n-1)(n-2).$$

Although the formula is mathematically correct, in practice such enormous number of collisions would not occur. Of course, the vehicles are not points, as assumed. As this question relates to the design of junctions, I do not propose to deal any further with it.

Mr. Fitzherbert has raised the question of control of advertising and the need for care in the location of petrol stations. The Joint Town Planning Committee of Bombay, of which I have the honour to be Chairman, have investigated both these questions and have drafted out suitable codes. This committee intend bringing these questions to the notice of Government as soon as they can.

Another point which this Committee is giving considered attention to is the siting of bye-pass roads. Bye-passes are of no value unless the bye-pass is protected from Ribbon Development, for in a few years the town moves to the bye-pass.

Note:—For comments of Messrs. C. D. N. Meares and W. L. Murrell on this paper kindly refer to their respective comments on paper K(II).

PAPER No. K (II).

LAY OUT OF ROADS

By

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Introduction.—This Paper has been compiled as a draft Chapter on "Layout of Roads" to be included in the proposed "Code of Practice for Roads" to be issued by the Indian Roads Congress.

Authorities for the standards proposed and the statements recorded are given as far as possible. An acknowledgment is particularly due to Lt. Col. W. B. Whishaw, O.B.E., M.C., R.E., for the use of certain material collected by him recently for a similar contribution.

1. *Traffic Surveys*.—An investigation of traffic conditions should be considered a necessary preliminary to the improvement or diversion of an existing road. Information should be obtained as to the volume and direction of the main traffic flows, the points of congestion and the cause thereof, the incidence of standing vehicles and development and industrial growth at the terminal points.

Such a survey should deal with a definite area rather than an individual road or junction within that area. Any restrictions placed upon the traffic using a particular road are likely to have an influence on the traffic conditions on other roads in the immediate vicinity. (1).

The method of compiling statistics will be as authorised in the forms already published by the Indian Roads Congress for traffic census.

2. *Public Safety*.—Public safety is of extreme importance in design of roads and has peculiar difficulties and problems for India in view of the diverse types of traffic using the highways. Segregation of fast and slow traffic, facilities for the passage of animals, pedestrians, prevention of encroachments and obstructions, should be given careful consideration and forethought. Many of the causes of accidents are due to unsatisfactory or inadequate legislation as regards highways and are therefore outside the control of the road engineer. But his layout should envisage future improvement and an easy realisation of improved traffic control when it can be attained as the result of public opinion, financial facilities or direct legislation.

In so far as existing road conditions are a contributory factor in the causation of accidents, their improvement demands a close study of the incidence of the latter. It is therefore recommended that map records of accidents, should be prepared and maintained by the Highway Authority in cooperation with the police. A detailed examination of these maps should be made at frequent intervals with a view to determining the points on the highway system at which accidents most frequently occur and by analysis to ascertain the remedial measures most likely to prove effective in their diminution. (1).

3. *Amenities*.—In studying alignments of roads, the effect upon amenities should not be lost sight of. The verges and the slopes of cuttings and embankments should be soiled and seeded or, in appropriate cases, turfed or planted with suitable shrubs. The treatment of these features should conform to the natural characteristics of the district and be made to harmonise so far as possible with the landscape. Grass verges should be adequately drained and kept clear of plant, bitumen drums, tar barrels, debris from the clearing of channels and waste material arising from the operation of road maintenance. Transverse grips or channels should be avoided as much as possible and efforts made to maintain the verges as tracks for horsemen, where this provision is necessary. (1).

4. *Acquisition of Land*.—When acquiring land for new roads or road widening, the opportunity of obtaining some return for expenditure on road works from owners whose lands are likely to be benefitted by the work should not be over-looked. (1)

The necessity of acquisition of land earlier than its immediate requirement is frequently of importance. This is particularly the case in dealing with old roads which are being developed to meet modern conditions and traffic and where the problem of suitable by-passes arises. It will be generally prudent

and economical to obtain possession of or an option on the land as soon as the alignment is fixed ; otherwise public safety and improved conditions may not be possible of attainment through prohibitive acquisition expenditure.

5. *Layout, Alignments and Grades in General.*—The alignment standard in rough country is most important in affecting cost of grading. The cost increases rapidly with increase in radii of curves and the longest radius should be consistent with the justifiable expenditure and service to be rendered. Expensive fills should be avoided without making alignment too crooked. A crooked alignment should not be used to reduce grades below the maximum accepted for the project. Curves adjacent to bridges should be avoided and tangents used at least for a short distance on each side of the bridge. The lowest cost profile can be obtained by the use of the "rolling grade". It is also pleasing in appearance if not carried to extremes, but safe sight distance must not be sacrificed. The top or weathered zone in many soil types is more suitable than certain of the unweathered zones, and sub-grades close to the original ground surface are likely to be more suitable than those in deep cuts and fills. Rolling grades when cuts are shallow, permit the use of such soils as sub-grades. Mistakes to be avoided are :—

- (1) Excessive reduction of intermediate grade,
- (2) Extra expense to get long straight grades,
- (3) Too few re-locations to secure reasonable maximum grades.

In mountain road location it may be economical to use short stretches of grade steeper than the long ruling grade, thus avoiding expense and dangerous alignment. Any excessive grade should be so compensated or so located as to permit its future reduction ; for example, a 9 or 10 per cent grade may be used for a short distance to reduce the cost of initial construction where higher standards are later contemplated. Allowance in grade should be such that on the reconstructed location the maximum will not exceed 7 per cent.

6. *Standard Road Layouts—Land Required.*—In designing and laying out new roads, the width of land to be acquired is of the utmost importance. Experience has shown repeatedly the extreme folly of not adopting certain minimum standard "right-of-way" widths, even if not required immediately or in the near future.

The minimum standard widths of roads should be :—

Class I	... *150	feet to 100 feet.
Class II	... 100	feet.
Classes III & IV	... 80	feet.

(*The maximum width should be insisted on when new trunk roads are laid out or where traffic conditions will obviously demand a 4-lane carriageway).

7. *Carriageway Widths.*—The 10 foot traffic lane for each line of rolling load traffic has been adopted by the Ministry of Transport and by the Indian Roads Congress Bridge Specifications.

The minimum width of metalled carriageway should be —

Class I Trunk Road or Urban	... 20	feet.
Class I Rural	... 10	„
Classes II, III & IV	... 10	„

9 (k)

In addition to these standards, additional widening will be dictated by traffic conditions.

No data or statistics are available, but it is recommended that any road carrying 2000 vehicles per diem, must be furnished with a minimum metalled surface of 20 feet.

In computing the number of vehicles, the effect and performance of the various types should be taken into consideration.

Assuming motor cars travel five times the average distance or five times the average speed of bullock carts per day, then one motor car causes the same obstruction to bullock carts as would be caused by 5 bullock carts; and alternatively, one bullock cart causes 5 times the obstruction of one motor car to motor cars. Therefore, if a road is primarily intended for motor cars, each bullock cart should count as 5 motor cars, and if the road is primarily intended for bullock carts, each motor car should count as 5 bullock carts for the purpose of determining the appropriate width.

8. *Radii of Curves.*—

Minimum radii of curves in plain roads 1000 feet (5 degrees curves).

Do. do. hill roads 50 feet (115 degrees curves). (2)

9. *Widening of Carriageway.*—(Formation).

If X = the extra width required on curves,

and R = the radius of curve,

then $X = \frac{(25)^2}{2R}$, 25 feet being the average wheel base of motor vehicle.*

The following table gives the required widening on curves of different radii for a unit width of road which may be assumed as 10 feet:—

Radius of curve in feet.	Recommended widening in feet.	Radius of curve in feet.	Recommended widening in feet.
50	12.50	550	1.00
100	6.25	600	1.00
150	4.25	650	1.00
200	3.00	700	1.00
250	2.50	750	0.75
300	2.00	800	0.75
350	1.75	850	0.75
400	1.50	900	0.75
450	1.50	950	0.75
500	1.25	1000	0.50

*["*Principles of Road Engineering*" by Messrs. H. J. Collins and C. A. Hart, page 318.]

10. *Super-elevation.*—Super elevation should be applied where practicable on all curves. The following table is intended to provide general guidance in dealing with super-elevation :—

<i>Radius in feet.</i>	<i>Super-elevation.</i>
Under 500	1 in 12 maximum.
500	1 in 16
600	1 in 18
700	1 in 20
800	1 in 21½
900	1 in 23
1000	1 in 24
1200	1 in 26
1400	1 in 28
1600	1 in 30
1800	1 in 31½
2000	1 in 33
2500	1 in 35
3000	1 in 36
3500	1 in 37
4000	1 in 38
4500	1 in 39
5000	1 in 40
Over 5000	1 in 40 to 1 in 48 according to the nature of the surface material.

Adverse camber should be eliminated before the commencement of the transition curve; super-elevation should commence at the tangent point and attain its maximum when the circular curve, if any, is reached. (1)

It is recognised that in built-up areas the degree of super-elevation is governed by varying factors and therefore each case must be considered on its merits. (1)

11. *Gradients.*—Ruling gradients should be :—

Plains	...	...	1 in 30.
Hill Roads	...	...	1 in 20.

Maximum gradient 1 in 15 in stretches not exceeding 300 feet. The gradient at curves should not exceed 1 in 30 and should be flat at hairpin bends. (2)

All changes of gradients should be effected by vertical curves.

12. *Visibility at Vertical Curves.*—In the case of vertical curves the maximum gradient should be 1 in 30 not used over a horizontal distance exceeding 200 feet and the rate of change of gradient should not exceed 1 in

100 per hundred feet measured horizontally and the summit of the curve should be made horizontal for a distance of 100 feet. A sight distance of about 550 feet will be thus automatically provided. (2)

13. *Visibility at Horizontal Curves.*—In the case of horizontal curves, the same minimum limit of visibility, 500 feet between approaching vehicles, should apply, and where this is unattainable, definition of traffic lanes is essential. Adequate visibility on curves on existing roads should be secured by increasing width of the inner verge or the removal of the slope on the inside of the curve when the road is in cutting. In planting verges and slopes on the inner side of a curve, trees, shrubs, etc., which at maturity may obstruct the view of drivers, should be avoided. (1)

14. *Traffic Lanes.*—The division of the carriageway into traffic lanes assists in the orderly movement of traffic and tends to promote greater safety on the highway. Lanes should not be less than 10 feet in width and the divisions between them should be marked by white or yellow lines or a combination of both. (1)

Stainless steel or rubber studs are more permanent than painted white lines, but are expensive in outlay. Carefully made setts or stone studs may be employed on hill roads with sharp curves, embedded into the road surface. The longitudinal joints of a concrete carriageway may with advantage be so arranged as to indicate traffic lanes.

When it is necessary to define traffic lanes at curves, the marking should extend 100 feet in each direction beyond the tangent point. The allowance for horizontal sighting should be greater on 3 lane roads than on 2 or 4.

15. *Camber.*—Excessive camber tends to the uneconomic use of the highway, induces drivers to keep near the crown of the road and may be a source of danger. A cross fall which is excessive for the material in use increases the tendency to skidding. For pure water bound macadam, a steep camber is essential in order to drain water away quickly and it is not unusual to find cambers of as much as 1 in 30. But with a waterproof surface this urgency disappears and all initial surfacing work should therefore include the elimination of excessive camber. The following table gives suitable camber for various types of material:—

<i>Type of surface.</i>			<i>Camber.</i>
Water bound macadam.	...	...	1 in 30
Tar Macadam and Bituminous Macadam	}	...	1 in 48 to 1 in 60
Asphaltic surfacing (concrete foundation)		...	
Concrete	...	...	1 in 60 to 1 in 70
Granite setts	...	...	1 in 40
Wood Blocks	...	...	1 in 50
Cast iron paving	...	...	1 in 90 to 1 in 100.

Super-elevation and local conditions may necessitate a departure from these cross falls. (*Adopted from Table 52, Page 304 of "Principals of Road Engineering" by Messrs. H. J. Collins and C. A. Harts.*)

16. *Drainage.*—Road drainage is of the utmost importance. The following conditions should be observed in layout :—

- (i) Offtake and outlet ditches to be of sufficient size, depth, and fall to carry away all water quickly from the road bed.
- (ii) Provide ditches of ample size, width, depth, and fall sufficient to carry away quickly water collected in them to the drainage structures or outlet ditch and at the same time ensure sufficient depth to keep the water level well below the sub-grade.
- (iii) Make all drainage structures crossing the road bed of sufficient size to permit free flow of water through them without retarding volume.
- (iv) Sufficient crown or camber should be provided to run off water into side ditches without erosion of surface or discomfort to traffic.
- (v) All springs and underground sources of water must be tapped and water led off by sub drains.

This particularly applies to the road ditches on the upper side of a road bed built on a hill side.

Where natural drainage is towards the road from the side, it is good practice to construct a wide ditch or ditches paralleling the road and outside the limits of the roadway to intercept the surface water and carry it to a proper outlet. This ditch or ditches should be in addition to the regular roadside ditch. (See also paragraph 18 below 'Boundaries of Road').

17. *Grass Verges and Tree Planting.*—Wherever possible verges should be interposed between paved areas, they should be of ample width, 6 feet being regarded as the minimum. (1)

Side tracks on land which is not immediately required for paved or macadamised road and which function as footpaths, or animal tracks, should be grassed where possible to avoid dust and preserve surface. Care should be taken that deposits of loose material, etc., do not preclude their use for such purpose. Too much attention cannot be paid in grassing, turfing or planting of shrubs, scent trees, etc., on new embankment or cutting.

Trees should not be planted nearer to the metalled road than 5 feet from the outer edge or toe of berm.

18. *Boundaries of Road Fencing.*—The precise demarcation of road boundaries is essential to avoid encroachment on road land. In India it is rarely a financial possibility to provide fencing at boundaries, but 'Burjis' or pillars of a permanent nature at suitable intervals should be established. In rural areas, the boundaries may be conveniently demarcated by a drain or dyke which can be suitably designed to carry away surface or storm water. (See also paragraph 16 "Drainage").

The excavation of such dykes at the outset should obviate to some extent the making of borrow pits. Roads on embankments and at their outer edge on hillsides need protection at the limits of the effective width of the highway ; in some instances this may be provided by turf or earth banks or stone walls or guard posts of tar barrels, rather than by a fence which may not be strong enough to withstand the impact of a heavy vehicle. (1) (adopted).

The fencing in of large areas for arboricultural purposes within the effective width of the highway, is to be deprecated as it forms obstruction to movement and passage of the public and tends to congest all traffic on a confined space.

19. *Parking Places*.—The parking of vehicles on the highways should be discouraged and provision made on land which does not form part of the highway. In designing new roads, the provision of such areas for the parking of buses and lorries should not be ignored as well as provision made for omnibus stopping places off the main carriageway.

20. *Service or Side Roads*.—The provision and upkeep of side roads should be considered a fundamental feature of road design and maintenance. At the outset such tracks will be rarely metalled or bridged or drained. But if they are kept clear of obstruction and maintained as a level and shady trackway, they will form the habitual roadway for many types of traffic, *e.g.*, pedestrians, animals, horsemen, etc. In urban areas and heavily trafficked sections, such tracks will eventually be found invaluable for segregation of traffic where and when additional paved lanes or metalled widening becomes necessary.

Special "Service" roads with arrangement to exclude bullock cart traffic may be used on unmetalled roads for light motor vehicles.

21. *Junctions and "Roundabouts"*.—(i) *New Roads*. The aim of design in the layout of road junctions should be to reduce the possibility of accidents to a minimum and to avoid delay and congestion. The anticipated extent and character of the traffic will largely determine the type of layout to be adopted, but physical conditions and the extent of land available are also factors to be taken into account. It is recognised that the ideal form of road intersection is one at which the two traffic routes cross one another at different levels. Wherever the future traffic needs may justify such measures, consideration should be given to the preservation of sufficient land for the subsequent construction of bridges and their approaches.

The following main principles should be borne in mind in designing road junctions :—

- (1) The number of intersections or road junctions on main traffic routes should be reduced to a minimum and spaced not less than 440 yards apart.
- (2) Road junctions in excess of four ways should be avoided except where there is ample space for a suitable "roundabout."
- (3) All subsidiary roads should join main traffic routes as nearly as possible at right angles. Acute angled junctions are to be deprecated.
- (4) At three-way intersections of important roads to be treated on the "roundabout" principle, the roads should as far as possible, meet at equal angles.
- (5) Where a minor road crosses a major road constructed with a single carriageway, the minor road should be staggered preferably to the left, and space provided at its junctions so that drivers can obtain the maximum vision before emerging into the major road. Where dual carriageways are provided, or intended, staggering is unnecessary if the minor road crosses the main traffic route at right angles,

but in the case of an oblique crossing staggering will result from the adoption of recommendation (3) above.

- (6) At crossing of two or more major roads ample space should be provided for a "roundabout".
- (7) At every road junction, the requirements of pedestrian and all other types of traffic should be studied and as far as practicable suitable provision made for them.

The "roundabout" which provides for continuous movement has the advantage of dealing with a greater volume of vehicular traffic than one where traffic is operated on the "Stop" and "Go" principle. In deciding the manner in which control is to be applied, the following principles are suggested for consideration:—

- (a) In built-up areas and in special situations where the expenditure involved in the construction of a "roundabout" may be excessive, due regard must be had to financial considerations in deciding upon the system to be adopted.
- (b) Where a road of major traffic importance is intersected by a road carrying a sufficient volume of traffic to require control, and the volume of pedestrian traffic is, or is likely to become considerable, preference should be given to traffic signals.
- (c) At junctions where an installation of traffic signals would seriously interfere with the fluidity of traffic, and particularly where there is a large volume of traffic making a right-hand turn, a "roundabout" is preferable, provided adequate weaving space is available.
- (d) Where provision for fluidity of traffic as referred to in (c), may eventually become necessary, traffic signals may be installed in the first instance but land should be acquired or reserved to provide for a "roundabout".

In the interest of safety, pedestrians should be discouraged from using the central island of "roundabouts" as refuges.

To screen the glare of on-coming headlights, the surface of the central island should be sloped to a height of 4 feet at the centre or planted with shrubs.

In towns where there is heavy pedestrian traffic, guard-rails should be placed adjacent to the kerbs with openings at pedestrian crossings. Where similar precaution is necessary in rural surroundings, the object may be more appropriately achieved by the planting of hedges which should be maintained at a height not exceeding 3 feet.

(ii) Improvement of Existing Junctions.—In the improvement of existing road junctions where traffic is considerable and sufficient space is available, a modified form of "roundabout" or central island may be introduced with advantage. The diameter of the central island should be as large as possible consistent with the space which may be available, and, in any case, should be sufficient to ensure easy and safe negotiation by the larger commercial and public service vehicles.

Experience has shown that large areas of paved carriageway with wide sweeping kerb lines encourage speed at road junctions and may be a source of danger to both vehicular and pedestrian traffic. Where there is insufficient room for a "roundabout" much can be done to improve traffic conditions at existing junctions by the judicious provision of refuges and re-alignment of the kerbs, the chief object in this case being to bring intersections between traffic streams to right angles as nearly as possible and to prevent turning traffic from taking the corners at high speeds. (1)

About 80 feet is the minimum diameter of the central island.

22. *Refuges.*—Refuges, if carefully sited, provide a valuable means of guiding the movement of vehicles at the same time increasing the safety of pedestrians when crossing the carriageway. It is desirable to leave a space or spaces across the refuge in the direction of the pedestrian crossing, level with the carriageway. The distance between the edge of the refuge and the kerb on the near side should not be less than 20 feet. Refuges at junctions should be so sited that the inside wheels of turning traffic are not forced to describe arcs of less than 30 feet radius.

All such refuges with their bollards or guard posts should be adequately illuminated. For the sake of uniformity and to avoid confusion with the tail lights of vehicles and other lights, it is important that such illumination should be white in colour. The overall height of the posts should be not less than 4 feet above road level.

The sign "KEEP LEFT" in white letters upon a blue ground as prescribed by the regulations, may be fixed on the top of the guard post. (1)

23. *Warning Signs. Sign Boards.*—Danger points on roads should be marked with the appropriate signal sign post placed at a distance of one furlong away and not less than 400 feet from the point of danger (2)

Signs and notice boards should not be allowed to fall into disrepair—those which are redundant should be promptly removed. (1)

24. *Siting of Underground Mains and Services.*—On all new roads, for the purpose of preventing interference with the carriageway, adequate verge accommodation should be provided for the laying of drains, underground mains, cables, etc., and their relative positions should be determined at the outset.

For pavements of a permanent nature, such as concrete, consideration should be given to the desirability of duplicating service mains and drains on each side of the central carriageway or on the outer sides of dual carriageways in order to avoid the subsequent breaking up of the carriageway foundation for service connections. Where it is anticipated that subsequent development will necessitate mains or services crossing the carriageway inconvenience and expense can often be reduced by laying short lengths of transverse mains or services before the carriageway is constructed. Boring machines can also be used to avoid disturbance of the carriageways. The adequate and prompt reinstatement of trenches in carriageways is of prime importance. To restore as far as possible, the monolithic character of the concrete foundations, the exposed edges should be prepared with a bevelled face and cut back to at least four inches beyond the width of the trench before reinstatement takes place. (1)

25. *Note on Hill Roads.*—The "pioneering" spirit which induces motor vehicles to operate on hill roads which were never designed for such traffic has been the cause of many accidents and disasters.

Road engineers are frequently called on by District Magistrates to express technical opinion on the safety or otherwise of such tracks for the passage of public vehicles. If the former insists that the standards, as laid down herein, must obtain before he can give a favourable reply, a large number of hill roads now habitually traversed by motor vehicles, would be closed to them.

On the advice of a technical committee, the Punjab Government have adopted "Safety Specifications" which must be established before public motor vehicles may be allowed to travel thereon.

The standards are for requirements of safety only and for *one way traffic* only :—

SAFETY SPECIFICATIONS.

(i) *Width* :—The clear width of the road in feet shall nowhere be less than the dimensions given in the following table : —

Table I.—Minimum width in feet.

(1) In open country, side slope not exceeding 1 in 2	...	12 feet.
(2) In bazars	... ..	12 ..
(3) In steep country, side slope exceeding 1 in 2 with curvature less than 20 degrees per 100 feet	...	8 ..
(4) In steep country side slope exceeding 1 in 2 with curvature 20 degrees—40 degrees (R=286 feet—143 feet)	9	..
(5) In steep country side slope exceeding 1 in 2 with curvature 40 degrees—60 degrees (R=143 feet—95 feet)	10	..
(6) In steep country side slope exceeding 1 in 2 with curvature 60 degrees—80 degree (R=95 feet—71 feet)	11	..
(7) In steep country side slope exceeding 1 in 2 with curvature over 80 degrees	... ..	12 ..
(8) On bridges	... ..	8 ..

(ii) *Gradients* :—The gradients shall nowhere exceed the figures given in the following table. This shows both the actual rise in feet in 100 feet and the equivalent cotangent (the length in feet corresponding to a rise of one foot).

Table II.—Maximum gradients

	Rise per 100 feet.	Equivalent to one in
(1) Curvature less than 20 degrees per 100 feet and on the straight	... .. 20	5.0
(2) Curvature per 100 feet 20 degrees—40 degrees	16	6.3
(3) Curvature per 100 feet 40 degrees—60 degrees	12	8.3
(4) Curvature per 100 feet 60 degrees—80 degrees	8	12.5
(5) Curvature per 100 feet over 80 degrees	... 4	25
(6) Average over 1000 feet length	... 10	10

(iii) Curvature :—The degree of curvature per 100 feet of length shall in no case exceed the figure given in the following table. The equivalent radius of curvature in feet is also given in column marked R:—

NOTE :—The degree of curvature refers to the angle turned through in a length of 100 feet and is equal to 5,730 divided by the radius of curvature.

Table III.—Maximum degree of curvature.

		<i>R</i>
(1) In open country, side slope less than 1 in 2	20 degrees	286
(2) In steep country slope from 1 in 2, to 2 in 1	80 „	71
(3) In steep country slope exceeding 2 in 1	150 „	38
(4) Hair pin bends 	286 „	20

The total curvature in a length of 1000 feet shall not exceed the amounts given in Table IV.

Table IV.—Maximum curvature in 1000 feet.

	One way traffic.
(1) In open country side slope less than 1 in 2	100 degrees.
(2) In steep country slope from $\frac{1}{2}$ to 2/1	400 „
(3) Do. do. exceeding 2/1	500 „

(iv) Parapet walls :—Strong parapet walls or railings shall be provided wherever the outside edge of the road is dangerous and wherever the distance from the outside edge to the centre of the road is less than the dimensions given in the following table. The centre will be measured from a point at least 5 feet from the inner edge of the road.

Table V.—Minimum distance from centre in feet without parapets.

	One way traffic.
Straights and re-entering curves and salient curves of less than 20 degrees 	6
Salient curves from 20 degrees to 40 degrees	7
Do. 40 „ to 60 „	8
Do. 60 „ to 80 „	9
Do. over 80 „ ...	10

It is for the consideration of the Indian Roads Congress whether such specifications amended or enlarged if required, should be published in the "Code of Practice".

BIBLIOGRAPHY

(1) Ministry of Transport Memorandum on the Lay-out and Construction of Roads, 1937.

(2) Minutes of the Business Meeting of the Indian Roads Congress, January 1938.

DISCUSSIONS ON PAPER No. K (II).

Mr. Trevor-Jones (Author):—The paper under discussion is largely based on the standards recently adopted by the Ministry of Transport for the United Kingdom (Ministry of Transport, Memorandum on the Lay-out and Construction of Roads—1937. Printed and Published by His Majesty's Stationery Office). In certain other cases I have incorporated standards recently laid down by this body and others suggested by Lt.-Col. W.B. Whishaw, O. B. E., M. C., R. E. In other cases I have proposed standards which have to some extent been arbitrarily chosen, but chosen with a definite view of their practicability. For, it seems to me no good laying down standards for this country which are too elaborate or too ambitious to be within the realm of practicable politics. It is no good having standards merely *Dekhne ke Waste*. For it is obvious that if such standards are laid down which are merely prohibitive, no progress can be made.

Mr. Mahapatra (Outtaok):—There are a few points on which I would like to make some suggestions.

As regards drainage (*vide* paragraph 16 of paper) I would suggest that the side drains should be kept shallow, just sufficient to drain off water in heavy rains. To prevent scours steep gradients should be broken into several steps by providing grade walls.

As regards grass-verges and tree-planting, (*vide* para 17 of paper) I would suggest that the avenue trees should be planted close to the outer edge of the roadside land, at a distance of at least 20 feet from the metal edge, or 5 feet from the edge of the side drain, whichever be farther from the centre of the road, and at an interval of 50 feet along the road.

As regards the boundaries of road fencing (*vide* para 18 of paper) I would suggest that a road should be demarcated on both sides by boundary pillars fixed against each furlong stone in straight portions and in curves at 200 feet apart or closer.

Rai Sahib Fateh Chand (United Provinces):—Lay-out of roads is a matter of great importance, for the cost of construction and maintenance and convenience of the traffic may depend a great deal on the proper lay-out.

As regards traffic surveys the hours at which there is extraordinarily heavy traffic should be noted as also the nature of the traffic.

As regards grades, it is better to give the proper gradient before the road is metalled. This avoids a lot of unnecessary expenditure and dislocation of traffic later on.

Regarding 'Standard Road-Width' I suggest that while sufficient width of road-land should be acquired, it is no use acquiring land in excess of the requirements, for, besides causing loss of land to the cultivator, the extra portion usually gets full of thorny bushes and unwanted shrubs which

often become the home of wild animals and it means so much of extra labour in taking earth for the road.

It is often necessary to reduce the road widths to the minimum in certain localities. The minimum standard road width should, therefore, also be specified. I think 80 feet minimum width for class II and 60 feet for class III and IV may be adopted.

As regards the 'Standard Width', I would like to observe that in the United Provinces the minimum width of metalled portion is 9 feet only instead of 10. The Hon'ble Minister of Communications, United Provinces wanted to know if an 8 feet road will not be sufficient to ensure speedy progress. We actually saw 8 feet wide Public Works Department roads in Bengal. The old-time roads as well as new ones in United Provinces are being made 12 feet wide. It is very necessary that the economic minimum of road width should be standardised, which will be such as will allow the middle portion of the metalled portion to be made use of by the traffic. Mr. Walker or Mr. Mukerjee might perhaps throw some light on the point as to why the Public Works Department in the United Provinces is in all cases, without exception, still increasing the width of its 9 feet roads to 12 feet instead of 10 feet as recommended by the Indian Roads Congress for a single lane of traffic. It becomes very difficult for an average District Engineer to decide what width to give under such circumstances.

As regards the 'Gradients', I think that a gradient of 1 in 30 is too much for plains. A gradient of 1 in 50 may not be difficult to achieve without much initial expenditure. This should be done atleast for the first and second class roads.

Regarding 'Camber' I would like to suggest that instead of the camber being fixed at 1 in 30, it should vary from 1 in 30 to 1 in 48, depending upon the amount of rainfall and other local conditions. In the United Provinces, the Public Works Department has laid down 1 in 48 as the camber for water-bound macadam while in Bengal we saw the camber of 1 in 30 on painted roads as well.

Standardisation of all these by the Indian Roads Congress will be of great help to District Engineers and others as well.

Mr. Brij Mohan Lal (Punjab):—In paras 6 and 7 of the paper the Author has referred to four classes of roads, but the basis of this classification has not been stated. As the method of classification of roads varies from Province to Province, a standard method of classification should also be suggested.

In para 7 the Author has suggested a width of 20 feet for 'Class I Trunk Roads or Urban' and 10 feet for 'Class I Rural'. The Trunk Roads pass through villages as well as cities, the major portion being through rural areas. The specification laid down for width is, therefore, very vague. Moreover a width of 10 feet is not quite suitable. It is always liable to 'rutting'. As a matter of fact in the modern conditions of mixed fast and slow traffic, a width of 20 feet is the only suitable standard for all roads.

except where traffic is insignificant. This standard is, however, too ambitious to be adopted. The next alternative is 12 feet. This width does not 'rut' and is more comfortable in driving. Therefore it is suggested that the standard should be 20 feet for class I roads and 12 feet for others.

In para 7 the Author has also suggested that wherever the volume of traffic is more than 2,000 vehicles per diem, the width of the road should be 20 feet. This limit of 2,000 vehicles is too much on the higher side. It is very difficult to show by mathematical calculations what this limit should be, but by observation of the traffic on Punjab roads, I am inclined to suggest it as 500 vehicles. An analysis of traffic statistics of Punjab Roads shows that there are only 500 miles in that Province which carry more than 500 vehicles per day. Driving in such miles shows that a motor vehicle has to pass on from the metalled portion to katcha berms about twice in each mile where the metalled width is less than 20 feet. This virtually means leaving the metalled portion about once a minute, and is too uncomfortable. The maintenance of the earth berms also becomes very expensive and difficult in such miles. It is, therefore, suggested that the figure of 2,000 be reduced to 500.

In para 9, the Author has given a table showing recommended widening in fact. The figures given in columns 2 and 4 of the table are twice of what is obtained by the application of the suggested formula. The widening suggested for 50 feet radius is too much, and would mean that on hill roads where the curves are all in the neighbourhood of 50 feet radius, the width should not be less than $22\frac{1}{2}$ feet anywhere. It is, therefore, suggested that the maximum widening should be limited to 5 feet for each unit width of 10 feet.

The suggestion made in para 20 regarding service roads is very useful, but as the finances cannot allow the metalling of these, bullock-carts cannot be expected to take to them, as unmetalled surface puts a heavier strain on the animals. They are, however, very much liked, if shaded, by pedestrians and animals.

The roundabouts and refuges recommended in paras 21 and 22 are essential for safety of traffic at busy crossings. The recommendations made by the Author are very suitable. Two roundabouts somewhat on the same lines were constructed at Lahore two years ago, and have proved very useful.

In para 25 the Author has given a copy of the standards laid down by a technical committee of the Punjab Government for hill roads used for one-way traffic only. Chakki Dalhousie Road—one of the most important one-way traffic hill roads in the Punjab, and one which does not fall under the category of those brought into use under the pioneering spirit, was judged by me from these standards, and it was found impossible to apply them in strict accordance with their details. All the standards have been fixed with relation to various degrees of curvature and slopes of countryside, and as both of these change incessantly along the road, it is not possible to judge correctly whether the standards are satisfied. The standards should, therefore, be laid in a much simpler manner. For example, in Table I, the minimum width has been specified as 12 feet for open country and bazars;

and 8 feet to 12 feet for various side slopes and curves, and only 8 feet on bridges. A specification of 10 feet minimum increasing to 12 feet on curves of radii smaller than 100 feet would have been much simpler. The specified width of 8 feet on bridges is too little. In Table II, a gradient of 1 in 5 is too steep to be specified even for flat curves and straight portions. A specification for a maximum gradient of 1 in 10 would have served the purpose better.

The radii of curvature specified in table III are too difficult to follow. Fixing of a minimum radius of 25 feet would be more suitable. The standards laid down in Tables IV and V do not at all appear necessary to be specified if the standards fixed for width, and the radii of curves are followed. These specifications, therefore, are only of an academic and theoretical value, and cannot be practically applied. They are, therefore, not suitable to be adopted by the Indian Roads Congress, and require amendment.

Mr. Syed Arifuddin (Hyderabad-Deccan):—We have all read the paper on Lay-Out of Roads by Mr. Trevor-Jones and I am sure, with great interest, which the importance of the subject demands from us. As he has stated in the Introduction, it is meant as a draft chapter to be included in the proposed: "Code of Practice for Roads". There is no doubt that the Author has taken a good deal of pain in collecting the information and putting it in the form in which it is now placed before the Roads Congress for deliberation. The subject is a very wide one and a good deal can be said on various points and more can be added. There are many points on which there may be a good deal of difference of opinion and quite justifiably too. Different experiences under different conditions have created different impressions on our minds and therefore our judgment with regard to the suitability of certain proposals must necessarily be different.

The subject by no means is yet exhausted. I doubt whether we can do justice to the paper of such importance by discussing it in the Congress at this stage, especially as the time given to us this year was much too short.

I would recommend that in addition to discussing the paper now further opinion of the members of the Congress may be invited and those who choose to give the opinion may send it to the Technical Committee by a certain date.

In this connection I would like to recommend one more thing. Instead of giving definite opinion, it would be more rational to think of the limits within which it may lie. For instance, refer to para 7 page 8(k). Carriage width proposed for 'Class I Trunk Roads or Urban' is 20 feet and for 'Class I Rural' it is 10 feet. It would be better before fixing it as a definite width to think within what limit the width ought to be. It is quite possible that for 'Class I Trunk Roads' the opinion may differ from 18 to 24 feet and for 'Class I Rural Roads' it may differ from 10 to 16 feet. Similarly opinion will differ with regard to the land required as mentioned in para 6. Here again if we form an opinion with regard to the upper and lower limit and then suggest what we consider to be a fair width I am sure it will be more correct and more useful.

I have some views of my own with regard to the practical ways of dealing with the survey operations which will not only avoid waste of time in doing unnecessary works but bring out all salient features, on which the alignment and the design of a road depends, in a very short time and with the least amount of labour consistent with the configuration of the country. I would like to place it before the technical committee, as I have not had time to deal with it here.

I would like to suggest here that like the table of super-elevation it would be better to print tables for vertical and transition curves. Similarly, a table may be added showing the widening of the road formation necessary at the inner side of the curve for different degrees of curvature and for different limits of visibilities.

There is an important point about which it will be better to obtain the opinion of various engineers and incorporate it in the Code. Some engineers have the opinion that the road must, as far as possible, be on a bank of at least 1 foot without which they do not believe that effective drainage can be obtained. They do not seem to have faith in the side drains, and for this reason they do not mind introducing many changes of grade. Particularly when the soil contains more clay and less grit, such as black cotton soil, they insist on bank. There are others who give greater importance to fewer grades and would like to propose long and easy grades consistent with economy, and for this reason they would adopt banking and cutting freely and would not mind if the formation line is just scraping the ground. They would depend on making the side drains efficient. Where banking can be provided without increasing changes of gradients unduly, they will gladly propose it. I, for one, hold the latter view. This matter must be thrashed out properly and final opinion should be incorporated in the Code.

Colonel G. E. Sopwith (Calcutta) :—The maximum super-elevation is suggested as 1 in 12 for radii less than 500 feet.

It may interest members that on the Frontier we used to have a rule-of-thumb (I do not know if it has since been revised) which proved very satisfactory. The formula was :

$$\text{Slope} = 1 \text{ in } \frac{R}{7}$$

with a maximum slope of 1 in 7, where R is the radius in feet.

For a radius of 35 feet, slope used would be 1 in 7 and also for a radius of 49 feet. For one of 100 feet, slope would be approximately 1 in 14.

The slope was uniform from the outside of the road to the inside drain.

Very elaborate calculations have been used for determining super-elevation in America and in Europe and are largely centered on the desirability of controlling speeds round curves. In India all important super-elevation is required on hill roads. Speed is controlled in many parts by time and distance methods and automatic control by variation in super-elevation is not a practical necessity.

I am aware that 1 in 7 is regarded in some areas as too high, especially for bullock-cart traffic, but the formula is a useful and simple one and the maximum to be allowed can be varied according to individual experience.

The maximum gradients given by the Author on page 16 (k) seem very large. In the Khyber, there is for a distance of about 2 furlong a gradient of 1 in 11. Motorists do not meet this with friendliness and I think they would view a slope of 1 in 5 with something approaching hatred.

Mr. M. I. D. Mufti (M.E.S.) :—Before I utter a word of criticism, I feel it my duty to thank the Author of the paper to whom we are indebted for the pains he has taken in compiling the draft chapter on Lay-out of Roads to be included in the proposed Code of Practice for Roads, to be issued by the Indian Roads Congress.

I am afraid, I cannot add much to what the previous speakers have already said but have a few points to observe :—

As regards 'Acquisition of Land' (*vide* para 4 of the paper), I would observe that the necessity for acquisition of land depends upon a number of factors which vary in each locality such as

- (a) Traffic conditions,
- (b) Width of the Road,
- (c) Cost of land.

As a result of my personal experience on Indian Roads, I suggest the land acquisition should be as follows :—

Class I	...	...	...	150 to 200 feet,
Class II	...	...	...	100 feet,
Classes III and IV.	...	...	...	80 feet.

In case the cost of land is high, the above figures may be reduced to 100 feet or more for 1st Class Roads and 60 feet for II and III classes.

In paragraph 6 of the paper the widths of roads in plains only have been given ; minimum widths required at hills should also be mentioned.

Paragraph 7 of the paper has already been dealt with by previous speakers, but it is not clear as to what would be the classification of Roads II, III and IV. The width in each case is shown as 10 feet ; it should be further elucidated. Moreover, in this there has been no mention about the total width required in each class of road including berms, as well as the widths over embankments and through tunnels. Under this paragraph, perhaps it will be preferable to mention the width of soling required for each class of road which is usually one foot more than the specified width of the road. In order to classify the roads, I wonder if we should also give some data with regard to the standards of traffic for which the road will be used.

As regards paragraph 10 of the paper 'Super-elevation' for curves of radii less than 500 feet should also be given. I suggest gradients between 50 and 100 and then from 100 to 500. Blind curves also need mention.

Regarding paragraph 11 of the paper, 'Ruling gradients' of 1 in 30 for plains seems too much. 1 in 18 or 1 in 20, I think, is good enough. It is preferable to mention maximum and minimum gradients.

The statement "Maximum Gradient 1 in 15 in stretches not exceeding 300 feet" is not clear. The gradient at curves up to 1 in 15 can be allowed, but this depends upon the radius of the curve.

As regards paragraph 12 of the paper, I would like to suggest that in long stretches of slopes, we should have horizontal portions of about 100 feet to 200 feet at distances of about half a mile.

As regards the camber for water-bound macadam roads, *vide* paragraph 15 of the paper, personally I think that in order to be able to keep the cars in control while driving at a high speed of say 40 to 50 miles per hour, it should not be more than 1 in 48.

As regards paragraph 17 of the paper, a distance of 5 feet from the edge of berm for planting trees seems to me too little. This should really depend upon the class of the road and should be more for narrow roads—10 feet from edge seems reasonable.

Regarding paragraph 18 of the paper, the 'minimum distance' of borrow pits from roads should be fixed. I suggest that it should be 10 feet.

As regards paragraph 25 of the paper, I would like to suggest that the width on culverts should be the full width of the roads and should be fully metalled specially on hilly roads.

The following points may also be added to the paper :—

1. Width and slope of berms : I suggest 4 feet and 1 in: 40 in plains.

2. Width of culverts : I suggest

Class of Road—	First.	Second.	Third.
Maximum ...	27 feet	24 feet	22 feet
Minimum ...	20 feet	18 feet	16 feet
Normal ...	24 feet	20 feet	18 feet

3. Head rooms in Tunnels and over Bridges : I suggest at centre—13 feet, minimum over side of roadway—8 feet, for all classes of roads.

4. Thickness of soling : This must depend upon traffic and the material of the soil over which the road is made. I suggest :—

(a) Using quarried hard stone ... 6 inches.

(b) Using Small boulders ... 9 inches.

(c) On embankments and soft places 9 inches to 12 inches.

Mr. Jagdish Prasad (Government of India) :—I would only say a few words on super-elevation, para 10 of the paper. I think the table of Super-

elevation is unscientific because the speed value of a curve depends on the deviation angle and the super-elevation, which is related to speed, should also depend on the deviation angle. For a curve of radius 1,000 feet, a super-elevation of 1 in 24 is recommended. A reference to "Curve Design" by the well-known authority, Professor Royal-Dawson, will show that this super-elevation is only suitable for deviation angles between 10 degrees and 15 degrees. For wider deviation angles, the super-elevation for the same curve will have to be about 1 in 10. Hence, the table is not correct for all deviation angles and it is correct only for a certain range of speeds. It is, therefore, desirable to have a table which gives values of super-elevation for a definite range of speed and for definite range of deviation angles.

A similar table for sharp curves on hill roads should be added so as to cover curves sharper than 500 feet radius.

Mr. J. N. Das Gupta (Calcutta):—We are all thankful to the Author for raising this very important question of lay-out of roads. Mr. Jagdish Prasad has referred to the points that I wanted to speak about. I would like to raise some points now about super-elevation. This is growing up in importance every day. Specially in case of arterial and interprovincial roads. The Author has suggested adoption of super-elevation without specifying the types of roads and the speed of the vehicle. For any fixed radius, the super-elevation necessary varies directly as the square of the speed of the vehicle and inversely as the friction of the surface which again depends on the surface condition.

From the table supplied by the Author in his paper, it appears that naturally he has adopted increasing rate of speed for increasing radii of the curves, and as far as I could work out it varies from a speed of 30 to about 60 miles an hour.

It would be very helpful to the members if the Author will enlighten us about the formula he has adopted for working out the figures in the table including the *constants* he has used, and if they were obtained as a result of experiments carried out or of observations made.

There is another point which strikes me in paragraph 15 as requiring some notice. The camber of 1 in 48 to 1 in 60 suggested by the Author appears to be unsuitable for places where there is a high intensity of rainfall, and the camber should, I think, be regulated by local conditions in setting up standards. The suggested camber may be alright when the surface is treated, but in ordinary macadam road in places and provinces where rainfall is high and very intensive, it appears to me that 1 in 40 would be rather on the low side sometimes. Camber in the neighbourhood of 1 in 36 would be the proper thing to adopt to ensure proper drainage of the road, so very essential for its proper maintenance.

Mr. K. G. Mitchell (Government of India):—I think we are probably all agreed that it is extremely difficult in so small a volume to cover all the ground. I agree with Mr. Arifuddin who has said that if you are going to condense it to this volume you must specify limits of dimensions instead of actual dimensions. Actually this Paper covers the space in which text books of hundreds of pages in length have been written by any number of people,

and it is extraordinarily difficult to condense it. At the same time, it is a very valuable contribution, in the first stage, of seeing whether we can evolve a general code of practice within broad limits and pointing out things which are to be avoided and which are at present practised and which are universally adopted throughout India.

I would like to make one or two remarks on the Paper in detail. It starts with traffic surveys. My proposal is that we should guard against having such surveys merely because you have them in some other countries. I think, in the conditions in India, if you are going to develop a road in any area, the best course is not to make a traffic survey on that road or track but to take traffic which has developed under similar road and agricultural conditions and under similar densities of population elsewhere, and that will give you much better result than any *ad hoc* traffic survey on the site. I remember the first road in the Punjab which we tried to improve as an earth road generally possible for wheeled traffic. Within a few weeks, all pack-traffic was replaced with bullock-carts, motor-buses and tongas, and any traffic survey made before improvement would have been useless. The only way is to take a similar road in a similar area and to see what the traffic is on that.

Then, in paragraph 3, there is a certain amount about "amenities" but there again I think that one of the principal things to remember in India is that the most common fault, again as Mr. Arifuddin has pointed out, is to make road on a high bank. There are a large number of road engineers who seem to have been educated on Railway Engineering text books. They get hold of the longitudinal section of the ground for a projected road and delight in using a long straight edge to get great lengths of one gradient regardless of unnecessary filling. High roads in modern conditions are dangerous and expensive to maintain. It is necessary to have roads that give you a feeling of comfort and safety at all times. Some of the best and most inexpensive roads in India are in Jaipur State in Rajputana. Of course, the cost of material is not high there. The crown of the metal is not more than 9 inches above the natural surface and you have got a wide formation, which is cheap to provide and to maintain, and you have the satisfaction that when you meet a bullock-cart, you do not risk its turning over. Too high banking, in my opinion, is one of the greatest defects of many of our roads and I think that is a most important thing to remember.

There is another point in regard to paragraph 5. Aesthetic considerations have to be remembered, but are often forgotten in the case of approaches to a bridge. Some of our bridges are works of art but the engineer plans, as far as possible, a straight run on and off, so that no one using the road ever sees the bridge in elevation. I do not suggest that you should put in tortuous approaches, for the sake of merely showing off your bridge, but where it is possible, the fact that a thing of beauty should be seen, should be borne in mind. I have no quarrel with what the Author says about avoiding curves on approaches to bridges—but if there are to be curves, then the lay-out should, if possible, afford a sight of the bridge.

Again in paragraph 7, I would like to say that although the Roads Congress has adopted 10 feet width as the standard traffic lane, I think this should be qualified by saying that single-lane bridges should be

12 feet wide. We have all sorts of traffic to deal with, not only vehicular traffic in regular lanes. I think, we should agree that for a single-lane bridge, 12 feet is infinitely better than 10 feet. In paragraph 7, the Author discusses standard width, from the point of view of classification based on importance of providing through communications. That is all very well if the important roads from that point of view also carry the densest traffic. But that is not the case. Traffic increases in proximity to towns, and almost any road within five miles of a town carries more traffic than the most important through trunk road in the depths of the country. The fact is that in this, as in so many other things, Indian conditions are peculiar—the ratio of short distance to long distance traffic being very high. One thing about widths which I would like to see absolutely standardised is that, through small towns and villages, all roads should be provided with say a twenty feet wide dust-proof surface. This is absolutely necessary for public safety and health. It is very easy to criticise, but I cannot refrain from remarking that the Author in paragraph 7 in suggesting standard widths, assumes that "Motor-cars travel five times the average speed of bullock-carts." Well, of course, bullock-carts go two miles an hour and I do not think that this is strictly accurate.

There is only one other minor point, I think, at the end of paragraph 17 about the width of avenues. There is a lot of argument as to what should be the width between trees across the road. People usually plant much too close because of the feeling that if you plant too widely nobody gets any benefit, for some years. But after a few years you find you are very cramped. That is a point on which I think something should be laid down. Again, in paragraph 17, the Author rightly emphasises that you should avoid deposits of loose materials on road lands so that the spare land may be used for bullock-carts and so on. You can remove loose materials but it is very expensive to fill your borrow pits, which should be prohibited ever more strongly.

In paragraph 19, parking place, I would add 'cart stands' also which are equally or more important.

Mr. C. D. N. Meares (Calcutta):—Only one comment suggests itself in these two papers read together. In Mr. Trevor-Jones' paper paragraph 4, page 7 (k) "Acquisition of land: When acquiring land for new roads or road widening, the opportunity of obtaining some return for expenditure on road works from owners whose lands are likely to be benefitted by the work should not be overlooked." Now if you turn to Mr. Trollip's paper, page 7(m), you will find he makes some very idealistic comments about service stations and petrol filling stations. We all agree it is very nice to have a station 40 feet from the road. I would like to ask him, however, who is going to pay for it. As soon as a road is built the land value goes up at once: if you then try and put up a service station the adjacent owners hold you up on the question of rentals. I would like to suggest that when any authority acquires lands, the question of petrol service stations should be taken into consideration. After all, I think you will agree, that petrol facilities should be considered a public service. As such, provision should be made for them when planning any new road or improving old ones, and land should be acquired for the purpose, while the road land itself is under purchase, otherwise the land value will go up to more than an economic limit for service stations.

Mr. K. E. L. Pennell (Assam):—I think it may interest members of this Congress in this subject of super-elevation on hill roads dealt with by Mr. Trevor-Jones, if I give a brief account of our practice in Assam. In the table given in Mr. Trevor-Jones' paper, it is assumed that the radius of the curve is known. I don't know whether other provinces are so fortunate as to have plans of all their roads showing the radius of every curve, but certainly in Assam we have nothing of the sort, and consider ourselves lucky if we have plans, showing the amount of roadside land, which can be treated as accurate with any degree of confidence.

The tables in Mr. Trevor-Jones' paper deal with curves of radii 500 feet and upwards. The majority of the bends in our hill roads have a radius of less than 300 feet.

When we started banking the curves on our hill roads the first thing to do was to discover their radii. The following procedure was therefore adopted (vide sketch in the note on "Banking Curves on Roads" reproduced on page 37 (k2) as Annex).

Thus all you have to do is to set up your prismatic compass at point A and find out the size of that angle. Then measure the lengths of the tangents A B and A C.

A reference to the table [vide Annex page 39 (k2)], which has been worked out on the drawing board and not from any formula, then gives you all the information you require to lay out your super-elevated formation levels.

I have sent the Secretary a copy of this diagram and table and hope that when it appears in the printed proceedings, it will be found much less complicated than it may now sound. Its great merit is its simplicity.

From practical experience gained while banking the curves on our hill roads, we evolved the following specification as regards the amount of super-elevation to be given:—

Super-elevation shall in no case exceed the following limits:—

For curves of radii up to 100 feet	... 1 in 6, i.e., 2 inches per running foot of road width.
100 to 200 feet	... 1 in 8, i.e., $1\frac{1}{2}$ inches per running foot of road width.
200 to 300 feet	... 1 in 12, i.e., 1 inch per running foot of road width.
300 to 400 feet	... 1 in 16, i.e., $\frac{3}{4}$ inch per running foot of road width.

There were two points mentioned by previous speakers I should like to comment on.

The first is regarding the maximum gradient permissible on roads in the plains.

As far as I could hear, suggestions ranged from gradients of 1 in 18 to 1 in 50.

In Assam we specify that the gradients on approaches to bridges, which have to be raised to allow country boats to ply under them, shall not exceed 1 in 40 and we prefer 1 in 50 to 1 in 60.

If you have steeper grades than these and take the bridge at over 40 miles per hour you get a bad bump. Flat grades for approaches to culverts are essential.

If you are travelling at 50 miles per hour and suddenly come on to a hog-backed culvert unawares, you emulate a rocket with often disastrous results.

The other point is the width of traffic lanes. Mr. Mitchell, I think, said that we ought to record 12 feet as the minimum width for the running surface of a single lane traffic road.

In Assam we cannot afford to make our bridges wide enough for two lanes of traffic, and have recently adopted 12 feet as the minimum clear roadway width. Several of our older bridges have a 10 feet clear roadway width only, and this has been found dangerous especially when passing pedestrians. Also, our road maintenance planers are over 9 feet wide which makes the passage of a 10 feet wide bridge a ticklish matter.

Mr. W. Lawley (N. W. F. P.):—Several speakers have already commented on super-elevation. This is of particular importance in the roads of the Bannu division where most people, to avoid the possibility of being sniped, are anxious to travel as fast as possible around corners. We vary the super-elevation according to the radius of the curve, with a maximum of 1 in 6.

Regarding road camber, to avoid 'rutting' caused by traffic hugging the centre of the road, we are now metalling some of our tar or bituminous surfaced roads almost level, *i.e.*, with a camber of 1 in 144, *i.e.*, $\frac{1}{2}$ inch rise in a 12-foot wide road.

I should like to say a word regarding the question of road widths. In the N. W. F. P., it is usually possible, within a few miles of any road, to find some sort of stone or shingle with which a strip of berm can be stabilized. Where such conditions exist, a minimum road width of 9 feet, and 16 feet for double lane traffic, is possible, and desirable in the interests of economy.

Mr. W. L. Murrell (Chairman):—These two papers are of the greatest interest to me because I was made responsible for a detailed reconnaissance of the Bombay-Calcutta Trunk Road in Bihar, and for the submission, last year, of the detailed estimate for about 50 miles of it.

As regards the over-all width of land required for a new project, I rather think that Mr. Trevor-Jones' figure of 150 feet is too low for a minimum, in the case of a modern Trunk Road.

In Bihar we are allowing for future dual ways for fast traffic, and for the segregation of slow traffic, for the Trunk Road.

The idea is first to construct two-road formations only. One of these will carry an 8 feet wide cycle track, plus mixed fast traffic. The other formation will carry the slow traffic.

These two initial formations have been arranged so that, when the time comes to have dual lanes for fast traffic, the present fast road formation can either be widened or duplicated, the culverts and minor bridges being duplicated.

The arrangement of the different formations is much too complicated a matter to discuss here, but it necessitates a land-width of 160 to 180 feet, even in fairly level country.

Where there are to be heavy fills or where side-slopes are steep, the over-all width required is even greater.

Even with these land-widths, and even including lands for permanent buildings, material and plant depots, parking places and additional width near habitation, the amount to be paid by way of compensation for permanent and temporary land acquisition is estimated to be less than 7 per cent of the total cost of the trunk road project. This includes the cost of acquiring "busti".

As regards the amount of surface widening which Mr. Trevor-Jones recommends for curves, presumably his amounts take into consideration only those cases where visibility is good.

I would suggest that the amount of widening be much greater for blind corners.

As regards super-elevation, it is noted that Mr. Trevor-Jones does not propose to allow a steeper super-elevation than 1 in 12 for curves of radii less than 500 feet.

Where visibility is good I think more speed should be allowed, and 1 in 8 is a more reasonable super-elevation for a curve of 50 feet radius, than is 1 in 12.

I am afraid I disagree entirely with the proposal that the gradient should be flat at hair-pin bends.

This seems to be a survival of the old days when the roads engineer stopped his *buggy* on a salient or spur to rest his horses and to admire the view.

There are many reasons why the level portion should be just on the up-hill side of the hair-pin bend :—

- (i) Having slowed down to take the sharp corner, the ascending motorist wants a level stretch of 100 to 150 feet above it in which to accelerate his vehicle,

- (ii) A level stretch just above the hair-pin bend helps the descending motorist to brake and slow down for the bend.
- (iii) Draught animals should be given a level stretch in which to rest. This level stretch must not be on a curve where visibility may be bad or where the motor vehicle requires room to swing. The proper place for resting animals is the straight level stretch just above the hair-pin bend.
- (iv) It is much more expensive to construct a hair-pin bend on the level than it is to construct one on a gradient.

I must admit that this is entirely my own idea, so far as I know, and that I have never yet seen the level section placed above the bend. I am so convinced that this is the correct place for it, however, that the Bombay-Calcutta Trunk Road in Bihar has been graded on this principle.

A point about tree-planting strikes me. To specify that trees should not be planted nearer than 5 feet from the outer edge or toe of the berm, may lead to many trees being cut down when the formation is widened.

Would it not be better to specify that the lines of trees on either side of the road should not be less than a certain distance apart—say 60 feet?

As regards boundaries, I think more care should be exercised in undulating country when making drains to serve as boundary marks. In Chota Nagpur many of these drains have developed into ravines and, in some cases, the road has had to be realigned because of the erosion started by a small, harmless-looking boundary drain.

As regards the particular colours which should be used for road signs, etc., I would suggest that we agree to some definite all-India practice.

In Chota Nagpur, we reserve red and white to go with black for all danger signs. Similarly, we reserve lemon-yellow to go with black to indicate place names and distances on road direction posts, and to give the travelling public any information as to the locality.

Though having too many colours is to be avoided, it seems necessary to have a fifth colour as suggested by Mr. Trevor-Jones, solely for traffic directions. White on a blue ground seems good for all-India practice.

Coming to Mr. Trollip's paper on Ribbon Development, one or two points in connection with the practice adopted in preparing the detailed project for the Bombay-Calcutta Trunk Road in Bihar might be mentioned.

The triangle of visibility has been taken with the Trunk Road side as 250 feet and the cross roadside as 150 feet.

Extra land is to be acquired for the parking of cars at points of view or at picnic sides, as well as depots for road materials and plant.

Control width:—In remarking on Mr. Trevor-Jones' paper, I stated that the land proposed to be acquired for the Bihar Trunk road was between 160 and 180 feet, on the average.

In addition to this, wherever the Trunk Road passes near existing habitation, I decided to take an additional 50 feet width on each side, making about 280 feet in all.

It had been my intention to use these 50 feet wide strips as buffer lands to avoid encroachment. The idea was for the local Government to lease out all these lands through the Khas Mahal Department for periods of about 10 years, as the Khas Mahal Department has the machinery for collecting rents and for defending title.

The detailed estimate for the Trunk Road was submitted before the papers of Mr. Trevor-Jones and Mr. Trollip were circulated, and it may prove of interest that the Bihar proposals lie between the recommendations made in these two papers.

Speaking not as Chairman to this meeting, nor as a Government delegate, but as an ordinary member, I would like to say that, as regards bye-pass roads, all engineers are agreed on the necessity for keeping "through" or Trunk Roads well away from densely inhabited areas. But, in India at least, the politician does not always agree and, sometimes, the civil authority would like to support the politician.

This over-shadowing of the engineer is possible even when the general alignment of a road across the country is being decided on. I would suggest to my brother engineers that this danger of interference should not be taken lightly, and we should, therefore, do our best either to educate others on technical matters, or agitate for constitutional reform that will result in giving more weight to the engineer's opinion.

Having worked on roads in other countries and having seen how extraordinarily quickly developments can take place as soon as the motor vehicle is given a chance, I feel that I am in a position to state that these two papers are most important contributions to the science of road design or lay-out of roads in India.

Time is getting short, but I feel that I must mention a book on lay-out and road problems which is in the Congress Library.

It is a report by the late Mr. W. T. B. McCormack, Chairman of the Victorian Country Roads Board, who visited the United States of America. In this report, one of the most brilliant road engineers of our day has picked out and described some of the finest features of recent American practice.

I see there are still others who have something to say on these two papers, but I am sorry that our time is up.

Would you members very kindly address your remarks as "Correspondence" on these papers, to the Secretary so that they can be printed with the Proceedings.

On behalf of the Congress I thank the Authors, Messrs. Trevor-Jones and Trollip, for their very interesting and valuable papers, also those

members who have spoken on the papers, or who will write on them.
— (Applause).

Mr. R. Trevor-Jones (Author):—If I reply to all the discussions and correspondence I have had on the paper, we shall be here for a considerable period, but I will try to reply, as briefly as possible, as I see we have only eight minutes left. I shall, therefore, refer to only a few of the questions put by each speaker. I think you are all very difficult to please; but I expected that.

Mr. Pennell and various other speakers want to introduce a steeper cross fall for super-elevation, steeper than 1 in 12. Mr. Pennell refers to a Public Works Department Paper where cross grade is as large as 1 in 8 for curves upto 100 feet radius. The Ministry of Transport in England will not allow a greater slope than 1 in 16 and although I have put in 1 in 12 for curves upto 500 feet, I think this is, if anything, on the steep side. I am fortified in these remarks from a recent paper in the Journal of the Institution of Civil Engineers by Mr. Aldington who gives reasons and calculations why cross falls should not be more than 1 in 16.

Mr. Brijmohan Lal, criticised the standard of 2,000 vehicles as too low for two-lane provision on metalled roads. He says that this would affect only about 500 miles of road in the Punjab immediately. As we have only 150 miles of two-lane metalling at the moment, an immediate increase to 500 would be a tremendous step forward in public safety and public amenity.

Mr. Mahapatra only wants trees planted on boundaries and 'whereabouts.' Apparently no double avenue will be entertained. There is a lot to be said for this, as trees on edge of formation are undoubtedly a danger to the motorists. But a double avenue increases shade for slow traffic on side roads.

I concur in Mr. Syed Arifuddin's idea that technical committee should now consider criticisms and opinions and prepare a final draft. My objections to his suggestions that there should be upper and lower limites for standards, is that the lower one will be adopted as the goal to be attained and a still lower one put into practice. Better to stipulate a minimum and stick to it as a general principle.

Mr. Surati states* that traffic roundabouts are now used for mixed (fast and slow) traffic. At one time I felt the same, but experiences, in Lahore, of roundabouts tend to prove that such is not the case provided the amount of traffic of either kind is not excessive.

Both Mr. Mitchell and Rai Sahib Fateh Chand criticise the 10 feet width units. As the 10 feet width has been adopted as the standard width for a single-lane of traffic in the Indian Roads Congress Bridge Specifications, it seems to me to be inconsistent to adopt another unit for the lay-out of roads.

* The comments of Mr. Surati appear under "Correspondence" on page 35 (k2)

Mr. Mufti complained that there are entire omissions about hill roads and so on. This, I agree, should find a place. As regards his remark that soling widths should be 11 feet rather than 10 feet, I think, this is a matter which should go in another chapter for this "Code of Practice"—possibly a chapter on "Design".

Mr. Fitzherbert * brought up the question of the siting of petrol pumps on cross-roads. At the moment I do not think this should be included in such a chapter as the one I have drafted. It is true that we have made a rule in the Punjab that pumps shall not be placed within 300 feet or 100 yards of a cross-road. There is some opposition to this, but on the other hand there is the question whether petrol pumps should be sited within the roadland at all.

Mr. Murrell criticised para 11, 'Gradients.' I can only say that these standards were adopted only last year by the Indian Road Congress, and as far as I am concerned, they are hard and fast axiomatic data. However, in considering the paper under review, no doubt the technical committee or whatever unit scrutinizes, will reconsider all standards previously adopted if they consider proper to do so. I am in full agreement with Mr. Murrell as regards the overshadowing of the engineer's advice by political or bureaucratic interests and short-sightedness. If we can produce standards which have the seal of the best professional opinion in the country, obviously the engineer has a weapon with which to fight the dragon of ignorance and prejudice. (Applause).

CORRESPONDENCE.

1. Comments made by Mr. W. F. Walker (Meerut) by post on Paper (k 2).

There is one point that I should like to raise and that is the question of level crossings over railways.

I find that in many cases where the road originally crossed the railway at acute angles the road has been given a serpentine curve so that the crossing shall be at right angles to the railway. This arrangement may have been satisfactory before the advent of fast motor traffic but under present conditions, in my opinion, it is a positive source of danger, because the motorist has his attention rivetted on the curving road and is unable to see whether a train is approaching and whether the gates are open or not.

In my opinion, the road approach to a level crossing should be straight so that the approaching motorist can see clearly whether the crossing is open or not.

There is one other point. I have found that in many cases railway sidings and signals are sited without any consideration for the convenience of road users. It is no uncommon thing to find a train standing across a main road merely because the danger signal, at which it is held up, has been sited without any reference to the road.

As regards 'road-widths', in my opinion, the additional cost of construction and of maintenance of a 12 feet road over a 9 or 10 feet road is not

* His comments appear on pages 28 (m) and 29 (m) under Discussions on Paper M.

justified. The 12 feet road also encourages passing motorists to stick on to the metalled surface to the last minute in the hope that they can squeeze past, whereas with the 9 feet road both realise that this is impossible and both give way keeping one wheel on the pacca. In this way the 9 feet road may be safer than the 12 feet road as well as more economical.

2. Comments made by Mr. H. M. Surati (Hyderabad-Deccan), by post on Paper (k 2).

Please refer to page 10 (k) paragraph 11 wherein "Maximum gradient 1 in 15 in stretches not exceeding 300 feet" is recommended. Can this be applied without any qualification of surface and nature of traffic? In case of a cement concrete road with 1 in 18 gradient, for a shorter straight distance of 200 feet it is observed that the drivers of loaded bullock-carts with great difficulty are able to negotiate downhill and instinctively the off-wheel and bullocks are directed on to the narrow earth-berm in the middle of their journey. I think there should be different maximum grade limits for different surfaces, keeping in view the nature of different traffic by which the road will be used.

Please refer to page 14 (k), para immediately under sub-para (7) of (21) wherein "roundabouts" are recommended for continuous movement of traffic resulting in greater flow as compared with 'Stop and Go.' It is submitted that almost all our cities have got a fair proportion of slow moving traffic and vehicles such as carts, horse-drawn vehicles, tongas etc.. Without any further regulation of traffic lanes, all vehicles, whether fast or slow-moving, take to the inner side of the road round the roundabout, causing considerable impediment to the movement of traffic on a fairly busy junction. Around a roundabout, the road becomes one lane for all vehicular traffic and can be of advantage only when the other kind (i.e. Slow or Fast) traffic is practically negligible.

3. Reply, by Mr. R. Trevor-Jones (Author), received by post, to the comments of Mr. W. F. Walker, on Paper (k 2).

I am grateful to Mr. Walker for raising the question of level crossings over railways. I quite agree that some specifications for such crossings should be provided in a chapter on the 'Lay-out of Roads' in the "Code of Practice." It might be of value to include certain items from the Government of India, Railway Department (Railway Board) "Classification of, and Standard Specification for, Level Crossings" No. I R. S. (M) 2 of May 1928, revised June 1931. Items 11, 12 and 13 of this appear to meet the points raised by Mr. Walker and these are reproduced for ready reference on the next page. At the same time the question of other crossings, such as water-courses and canals, should be specified, and for want of other data, I suggest the Punjab practice taken from the Public Works Department Buildings and Roads Manual of Orders, paragraph 8(78) which might serve the purpose. The classes of road referred to are merely provincial and will have to be suitably amended when classes are adopted and defined by the Indian Roads Congress. At the same time, as I mentioned at Calcutta, it is possible that such a specification will be more suitably included in a chapter on 'Design of Roads'. It is a mistake to provide and make the field of the chapters in question too wide.

Details.	Dimensions, etc. for various classes of crossings.					Remarks.
	"Special."	"A" Class.	"B" Class.	"C" Class.	"D" Class.	
11. Angle of crossing between gates.	Not less than 45° between centre lines of road and railway.	Same as for "Special".	Same as for "Special".	Same as for "Special".	At right angles to the centre lines of the railway.	
12. Minimum length of straight portion of road outside gates.	40 feet	30 feet	20 feet	10 feet	Nil.	On important roads, except in hill sections, these dimensions should, when the cost will not be too great, be increased to 100 feet for "Special" and "A", 75 feet for "B", and 50 feet for "C" class level crossings.
13. Minimum radius of centre line of road on curved approaches within 150 feet of the centre line of the railway.	200 feet	150 feet	100 feet	70 feet	25 feet	

ANNEX.

BANKING CURVES ON ROADS*.

This note has been prepared on the experience gained on roads in the Khasi and Jaintia Hills Division ; it is intended to serve as a guide to the lines on which this work should be carried out

2. The super-elevations shown in the table are in accordance with those given in Assam General Specification No. 81 (1) and with those adopted on the Shillong-Gauhati and Shillong-Sylhet roads, *i.e.*, on controlled one-way traffic roads and appear suitable for metalled roads through *teelaks* but it may be found that for metalled plains roads it is preferable to reduce them to those given below for gravelled roads.

3. For gravelled roads both in the plains and through *teelaks* the super-elevation must be reduced to the maxima given below as, if made too steep, the gravel has a tendency to be washed off the banking.

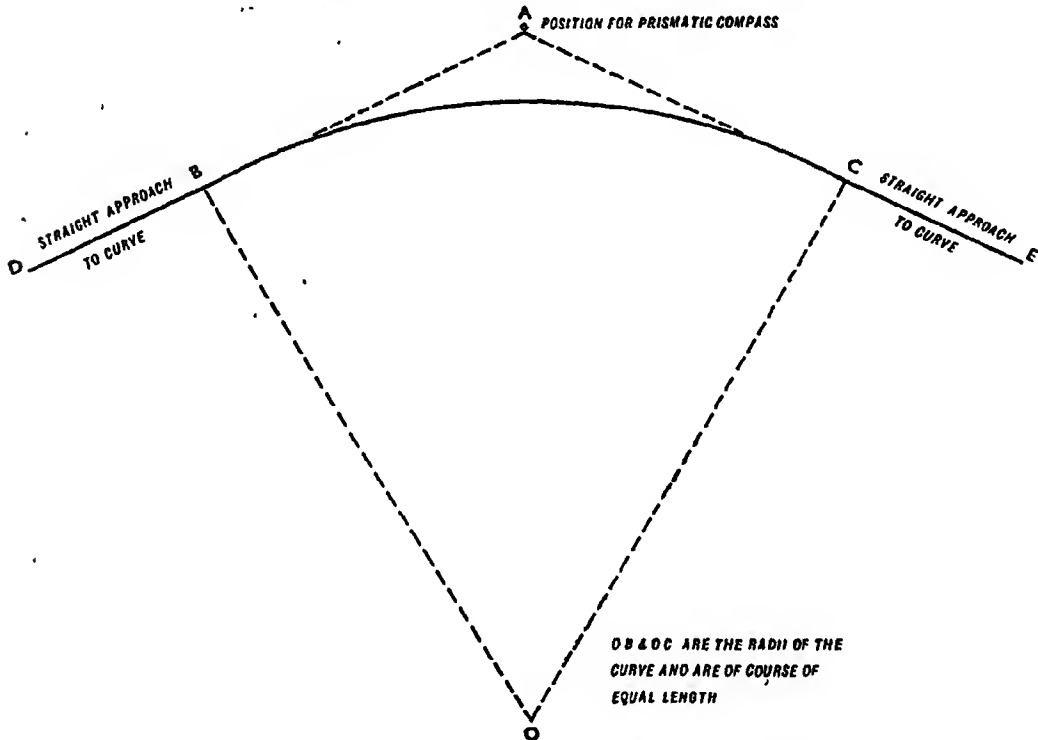
Maximum super-elevation for gravelled roads.

For curves of radii up to	Maximum super-elevation,		
100 feet	1 in 8 or $1\frac{1}{2}$ "	per r.ft	of width of road.
101 to 200 feet	1 in 12 or 1"	do	do
201 to 300 feet	1 in 16 or $\frac{3}{4}$ "	do	do
301 to 500 feet	1 in 24 or $\frac{1}{2}$ "	do	do

Consequently when using the table for banking gravelled roads, the super-elevations given in column 4 must be reduced in accordance with the above maxima and the length of the radii shown in column 3 of the table.

* This note has been referred to in Mr. K. E. J. Pennell's speech on page 28 (k 2).

4. *Instructions regarding the use of the table.*—Experience has shown that the majority of curves on any hill or *teelah* road have angles (marked A in the sketch) varying from 100 to 160 degrees and that the lengths of the tangents (marked AB and AC in the sketch) vary from 50 to 100 feet.



The tangents AB and AC must be of equal length and as in practice it is difficult to see exactly where the tangent meets the curve at B and C it is best to measure along the road on both sides and take the mean length.

The following table shows that the radius OB and OC of the curve varies much more with the angle A than with the length of the tangent which is fortunate as it is easy to measure this angle accurately with a prismatic compass.

Having found the angle A and the length of the tangent a glance at this table shows the banking required and no further calculation is necessary as the length of the radii for intermediate angles and lengths of tangents can be arrived at near enough from the nearest given figures.

5. The super-elevation as calculated will be given throughout the whole length of the curve BC. The length of the approaches BD and CE will be :—

100 ft.	for a super-elevation of 2" per r.ft. of metal width
80 ft.	" 1½" do
60 ft.	" 1" or under do

the super-elevation rising uniformly from zero at D and E to the full amount at the commencement of the curve at B and C.

When two adjacent curves are so close to one another that there is not room to give the full lengths as laid down above for the two approaches:—

- (a) There will be no zero point, the two approaches being laid out as above from the adjacent ends of the two curves to the points where the super-elevation falls to $\frac{3}{4}$ " or $\frac{1}{2}$ " per r.ft. of width, the remaining intermediate length being laid with this amount of super-elevation.

- (b) A length of at least 10 feet must be left between the starting, zero, points of the two approaches whose lengths must be reduced but kept approximately proportionate to the lengths given above.

6. Table for the banking of curves on metalled roads :—

Angle at A degrees.	Length of tangents AB and AC in feet.	Length of radii OB and OC in feet.	Super-elevation or banking in inches per r.ft. of width.	Remarks.
1	2	3	4	5
100	100 80 60 50	119 95 71 60	1½ 2 2 2	2" per r.ft. is the maximum banking permissible.
110	100 80 60 50	142 113 85 71	1½ 1½ 2 2	
120	100 80 60 50	173 138 103 86	1½ 1½ 1½ 2	
130	100 80 60 50	213 170 128 107	1 1½ 1½ 1½	
140	100 80 60 50	273 217 164 136	1 1 1½ 1½	
150	100 80 60 50	Over 300 292 220 183	¾ 1 1 1½	
160	100 80 60 50	Over 300 Over 300 334 282	¾ ¾ ¾ 1	

7. *Metalled roads with an excess thickness of metal :—*

- (a) The normal thickness of well-consolidated metal may be taken as 6 inches over soling and 9 inches where there is no soling.
- (b) Thus for curves where the super-elevation is small, it is often possible on roads having an excess thickness of metal to obtain sufficient filling for the outer portion of the curve by digging up the inner portion to the correct slope until the normal thickness of metal is obtained at the inner edge and using the metal thus obtained for raising the outer portion.
- (c) As metal thus dug up is full of dust, it must be screened through a $\frac{1}{2}$ inch mesh screen. A screen made of expanded metal as per plan enclosed [page 43 (k2)] has been found very useful as with one operation it separates out metal, chippings and dust.
- (d) When the cross-section of the road has been brought to the correct slope and dry-rolled, these chippings should be spread as blindage over which the renewal metal coat is laid so that on rolling, the blindage works up through the new metal from below which locks the metal much better than when worked down with water from above.
- (e) On roads having no excess metal or where the super-elevation is so great that even on excess metalled roads the correct slope cannot be obtained by digging and filling, or by the addition of a few inches of extra thickness of new metal along the outer edge, it is usually economical to use soling stones instead of extra metal.
- (f) Where soling stones are used it should be decided in each case whether it will be economical to dig up the metal along the outer portion till the old soling is exposed and to build up on that with fresh soling thereby obtaining a large amount of old metal which can be utilised after screening as stated in paragraph (c) above, or to lay the soling direct on the existing surface. In any case a consolidated thickness of at least 4 inches of metal must be given over the soling.

8. *Method of laying-out banking slopes.*—Experience on the roads in the Khasi and Jaintia Hills Division has proved the following to be much the simplest and quickest method for giving the necessary profiles.

(a) Tools and materials required :—

- 1 ordinary template for a metalled road
- 1 straight edge 16 feet long
- 1 carpenter's spirit level
- 1 measuring rod 4 feet long marked in inches from 1 to 40
- String
- Pegs
- Hammer.

(b) Take the inner edge of the metalling as datum. The dug-down level as explained in paragraph 7 (b) above, should be taken for roads with excess metal. Start at the zero points D and E [*vide* sketch on page 38.(k2)] and after checking the cross-section with the template, drive in pegs at the outer edge of the metalling and mark the correct level on them.

Next drive in pegs at points B and C also on the outer edge of the metalling where the full banking commences and mark on them in pencil the height of the finished road surface. An example will show how this height is arrived at:—

Assume the metalled width is 12 feet and the banking slope as per table is found to be $1\frac{1}{2}$ inches per foot width. The outer edge of the road has therefore to be 18 inches higher than the inner edge. Stand the measuring rod on the inner edge immediately opposite the peg and place the straight edge against the 18 inch mark. Level it up with the spirit level and mark where it cuts the peg. If pegs B and C are any distance apart, intermediate pegs should be given and similarly marked.

(c) Since the approaches BD and CE may be anything up to 100 feet long, intermediate pegs are required for them also. Keeping to the above example the approaches for a $1\frac{1}{2}$ -inch bank are 80 feet long—*vide* paragraph 5 above

Drive in pegs along the outer edge of the metalling at the $\frac{1}{4}$, $\frac{1}{2}$ and $\frac{3}{4}$ distances, *i.e.*, 20 feet, 40 and 60 feet respectively from D and E where the cross slopes will be $\frac{3}{8}$ inch, $\frac{1}{2}$ inch and $1\frac{1}{8}$ inches per r.ft. of width respectively giving differences of level between the outer and inner edges of $4\frac{1}{2}$ inches, 9 inches and $13\frac{1}{2}$ inches respectively.

Using the measuring rod, straight edge and spirit level as explained above, mark these heights on each of the pegs.

Connect up all the marks on the pegs from D right round to E with a string which then gives the level of the finished road surface.

(d) When laying the soling remember, there will be 4 inches of metal over it so the soling surface must be kept 4 inches below the string level.

Check the slope frequently when laying the soling by the straight edge, one end being on the datum level at the inner edge of the metalling and the other on the string along the outer edge and remember, the soling surface is to be kept 4 inches below this line.

9. *Banking gravelled roads.*—(a) All the gravel lying on the length between the zero points D and E of the two approaches must first be salvaged by scraping it off on to the berm along the inside of the curve.

(b) Fix the string showing the finished level of the surface along the outside edge of the curve as explained above and earth up the road to the correct slope checking with the straight edge as necessary.

(c) As soon as the new earthwork has consolidated and become in a fit state for gravelling, re-spread the salvaged gravel.

10. *Berms*.—(a) The outer berms are to be earthed up in continuation of the slope given to the metalled surface so that even if a vehicle gets on to the berm it is still at the same slope as it would be on the metalled surface.

(b) On excess metalled roads where the inner edge has been dug down the inner berm must be correspondingly lowered and given a gentle slope to the roadside drain which will probably have to be deepened.

(c) In all cases both for metalled and gravelled roads the inner berm should be only given a gentle slope towards the roadside drain or edge of the embankment and grass encouraged to grow on it.

Enclos :—Sketch of screen referred to in paragraph 7 (c).

<i>Dated Shillong :</i>	}	K. E. L. PENNELL,
<i>The 7th August 1936.</i>		<i>Superintending Engineer, Southern Circle, Assam.</i>

PAPER No. K (I)

Mr. K. E. L. Pennell (Chairman) :—I call upon Mr. R. Trevor-Jones to introduce his paper K (I), on "Collection of Material for and Consolidation of Water-bound Macadam".

The following paper was then taken as read .—

PAPER No. K (I).

COLLECTION OF MATERIAL FOR, AND CONSOLIDATION OF,
WATER BOUND MACADAM

BY

R. TREVOR JONES, M.C., M. Inst., C.E., I.S.E.,
Superintending Engineer, P. W. D., Punjab.

Introduction.—*This draft is prepared with the object of arriving at Standard Practice in Water-Bound Road Construction.*

The subject matter and data have been obtained from specifications authorised by Local Governments, etc., of the following provinces:—

<i>Bengal,</i>	<i>Delhi,</i>
<i>Madrās,</i>	<i>Assam,</i>
<i>Bihar,</i>	<i>Sind,</i>
<i>Orissa,</i>	<i>N.W. Frontier Provinces,</i>
<i>Punjab,</i>	<i>Central Provinces & Berar,</i>
<i>United Provinces,</i>	

and from the Military Engineer Service Handbook, Vol. III Roads and "Road Construction and Maintenance in India"—Engineer-in Chief's Technical Paper No. 10

1. *Collection in stacks.*—Metal should be stacked at roadside in continuous stacks of uniform sections leaving only such gaps for drainage as may be ordered by the engineer in charge. It is important that such stacks are located absolutely clear of the road formation, (*i.e.*, outside the road berms). In hill sections, metal should be stacked on special platforms or sidings located off the roadway at suitable intervals (say two furlongs).

2. *Measurements.*—In order to allow for loose stacking, stacks should be 13 inches high but measured as one foot. The stacks should be of such section as to give sufficient metal for the stipulated thickness of coat on the corresponding length of road. "Farmas" or gauges, should be constructed accordingly and checked periodically.

3. *General.*—Metal should not as a rule be collected before it is actually required. Consolidation should not commence until all metal required in the mile or portion thereof concerned, has been collected and measured. Collection and consolidation should be usually carried out by full miles except in large cities and towns.

(Note on Design of Water-Bound Macadam.)

It is usual in India to specify a $4\frac{1}{2}$ inches thickness of metal. This is in all probability heavier than necessary particularly if the surface is to be water-proofed. In an ordinary water-bound macadam road, the metal is all, more or less, of one size and consolidation is obtained by cementing the stones together by rolling dry and then wet.

Each piece of metal is bedded in splinters, and chips are broken off by intensive consolidation. The remaining voids are grouted with stone dust formed by traffic.

Working by this method a thick coat of metal is a necessity since consolidation of a thin coat cannot be effected.

If the metal is properly graded, a much thinner coat can be used. Each piece of metal is embedded in smaller pieces specially put there by proper grading. The voids are filled with clay and stone dust which should be forced up from underneath during consolidation. This grouting material has a far better bedding effect than stone dust alone. The bedding of each piece of metal is the most essential feature of the wearing properties of a road as it is the gradual wear of one particle against another which finally accomplishes its destruction. This wear will not occur if the metal is bedded in properly.

Grading the stone means that the proportions of each size are so arranged that there is a minimum of voids in the mass of the aggregate. The object of pre-grading the metal is to reduce to the minimum the interstices between the particles when they are laid, and thus to cause the particles to interlock and form a full bonded surface. Pre-grading is particularly advisable where thinner coats of metal are used. If the metal is all of one size it will not interlock properly and there will be large and numerous interstices. Such a surface, though it may look all right at first, tends to disintegrate rapidly under traffic and the road breaks up.

In order to secure proper grading, a representative test should be made of the metal in the consignment being used.

3 (k)

As an example, a suitable grading might be:—

1 inch to $\frac{3}{4}$ inch	...	35 per cent.
$\frac{3}{4}$ " to $\frac{1}{2}$ "	...	30 "
$\frac{1}{2}$ " to $\frac{1}{4}$ "	...	30 "
Stone dust filler	...	5 "

Take about 5 cubic feet of the metal that is supplied. Find out the proportions of each of the above by screening them out of the sample.

Should a variation of 10 per cent or more appear in any particular size it is better and easier to add a fixed amount of any size deficient than to attempt to screen out an excess.

4. *Surface Scoring*.—The surface of the old metalling or of the soling as the case may be, should be thoroughly cleaned of all dirt. In the case of old metalling, ridges should be cut and metal thus obtained used to fill ruts. The whole surface should be then scored with lines about $1\frac{1}{2}$ inches deep and about 12 inches apart, in order to provide a key. The full working width must be demarcated with picks working along properly aligned strings.

(NOTE:—In certain localities it is customary to place $\frac{1}{2}$ inch layer of earth or "moorum" to act as a cushion and to work up between interstices of metal. The efficacy of this arrangement is doubtful).

5. *Edging of bunds or "Daulas"*.—When the old surface has been brought to the camber that the finished road is to have, two parallel bunds of clay puddle, 9 inches wide and 6 inches deep, should be made along the outer edges of the metalling. The bunds should be laid straight, true and parallel, having a distance between them equal to the width to be metalled. The bunds should be strong enough to prevent the new metal from spreading as well as to retain the water used in consolidation. A 12 inches width of berms will be made up at the same time to act as backing for the bunds.

6. *Camber*.—If the consolidated macadam is to be surfaced with a water-proof substance, such as Bitumen or Tar, the camber should be not steeper than 1 in 60. If surfacing is not proposed, the camber should be not steeper than 1 in 36 or flatter than 1 in 48. (See also para 15 on "Camber" in Paper No. K (II) on "Layout of Roads").

7. *Super-elevation*.—See para 10 on 'Super-elevation', in Paper No. K (II) on "Layout of Roads".

8. *Spreading Metal*.—The metal should be raked off the stacks with baskets, screened if dirty, and spread evenly over the surface to make up full coat required. The metal should be handpacked, bigger pieces of metal being placed below and smaller pieces in the interstices of the larger. There should be no necessity to withhold any metal to fill up places which sink on rolling if work in paragraph 5 above has been properly carried out.

9. *Templates*.—The metal should then be spread between the bunds to the camber of the templates provided. Three templates should be used with a distance of approximately 25 feet between each. The top layer of the metal should be dressed by hand between the templates. The templates should be removed in rotation so that the last two templates are always in place to level up the new length. When a template is removed, new metal should be added and packed by hand and the void filled up. On corners, similar templates are required but with straight profiles in place of cambered

profiles. Sets of these for different cross slopes ($\frac{1}{7}$, $\frac{1}{10}$, $\frac{1}{15}$, and $\frac{1}{20}$ should suffice) are required and each must be clearly marked with its slope.

The transition strips between cambered sections and banked curves must be spread by eye as gauges or templates cannot be used. But in all cases the edges to the metal must be clearly defined by lines.

10. *Level*.—A spirit level should invariably be used with the template to ensure that the edges of the metalling are truly level.

11. *Rolling and Consolidation*.—The metal should then be rolled, commencing at the edges and working towards the centre. The metal is to be dry rolled until well compacted and there is to be no appreciable movement in the metal when walked upon, or no appreciable wave in front of an advancing roller. The whole metalling should then be thoroughly watered and kept saturated and the rolling continued until the consolidation is finished to the satisfaction of the engineer in charge.

(A rough test for finding, if consolidation has been satisfactorily completed, is that a loaded cart should leave no indentation when passing over the finished work. Another test is that if a piece of metal about the size of a walnut is put on the surface and a roller passed over it, it will be driven in, if the consolidation is incomplete, but will be crushed when it is finished).

12. *"Bajri" Binding or Blinding*.—When consolidation is practically complete and not any earlier, the blinding material or "*bajri*" which has been provided (and which should contain no clay or organic material) should be spread evenly over the whole surface and be of such a thickness as will when watered and rolled, only just fill all interstices. After the spreading of the blinding material, the surface should be well rolled and watered to such an extent that the blinding material is formed into a slurry. The slurry should be brushed slightly with besom brushes backwards and forwards in front of the working roller and the rolling and brushing should continue until the surface is passed by the engineer in charge.

Not more than one furlong of road should be under operation in any one mile at one and the same time.

13. *"Bajri" Measurements not to be added*.—The blinding material should be absolutely free from dust, sand or clay and should be screened before use, if necessary. The cubic contents of the blinding material should not be measured and paid for separately from the metal, the spreading and consolidation of such *bajri* being included in the rate for consolidation.

14. *No admixture of earth*.—No earth or other material should be mixed with or spread over the metal, before, during, or after the consolidation. Where stone is completely devoid of any binding property and no small stuff obtained from scarifying, or separate collection, is available for this purpose, earth may be used (after obtaining the written consent of the engineer in charge); provided that the earth used is not more than 5 per cent of the stone consolidated, and is not added till the stone metal has been compacted.

15. *Progress*.—Unless approved by the engineer in charge, one day's progress for one steam roller should not be less than 3000 square feet or more than 4000 square feet (*i.e.*, in terms of a 10 foot width not less than 300 feet or 100 yards or not more than 400 feet or 133 yards).

Metal should not be spread more than 250 feet in advance of consolidation.

NOTE:—Considerable difference of opinion seems to exist as to the efficient steam roller output per diem, viz.,

Punjab 8000 to 4000 square feet.

Military Engineering Services Handbook, Vol. III page 150, 700 cubic feet $4\frac{1}{2}$ inches thick, 12 feet wide, or say 1870 square feet.

Madras } 1000 to 1500 square yards, say 9000 to 13500 square feet
Orissa } (a furlong 16 feet wide).

16. *Watering completed work.*—After consolidation, the finished surface should be kept wet for one week—this watering being included in the rate for consolidation.

Care should be taken that no portion works loose for at least a month or until surfacing is carried out.

17. *Making up Berms.*—Work on making up berms should be at no time, more than two furlongs behind the consolidation work. Earth for the berms should be taken from borrow pits, the edge of which should coincide with the boundary of the road land. The borrow pits should be rectangular in shape, of uniform depth and unless otherwise specified, with lengths and breadths of multiples of 5 feet. Measurement for earth work in berms should be those of the borrow pits. In towns and built-up areas, earth for berms should be imported.

18. *Profile of Berms and Sides.*—Berms should be made up to full formation width, with straight edges and properly dressed side slopes. The earth should be spread after all ruts have been filled. All clods should be broken.

19. *Closing Road Diversions.*—Where scarifying, spreading of metal or consolidation is to be done, the road should be closed to traffic. Whenever it is possible to provide a proper diversion, the maximum length closed may be equal to one day's work of consolidation plus 250 feet for spreading. When such diversion is not available, all consolidation scarifying and spreading should be done in such short lengths as the engineer in charge may direct. Diversion tracks should, as far as possible, be beyond the berms and should be carefully maintained.

20. *Barriers, Chaukidars, Lights.*—The road should be closed by the erection of barriers at both ends which should be suitably lighted at night. During day light, a man with red and green flags must stand about 25 feet in front of each barrier directing the traffic. Night watchmen must also be provided to see that the lights burn all night.

DISCUSSIONS ON PAPER No. K (I)

Mr. R. Trevor-Jones (Punjab):—I feel my paper deals with a very simple subject but at the same time an extremely important one. We have all realized that for many years to come the water-bound road will be the road for India; but my paper is nothing more than a compromise. To begin with, I have had no experience at all of roadmaking in India other than the Punjab, and I have merely had to work on as many specifications as I have been able to get from various authorities in India. Whether it is possible to draw up a specification which will be suitable for the whole of India remains to be seen. In my opinion it will probably be necessary to have at least 3 or 4. For instance, a specification for water-bound which is meant to be water-bound only, and for water-bound which is to be tarred, must necessarily differ in essential details. Also when you have a wide divergence in local conditions, rainfall, geology, soil, material, etc. it is going to be very difficult to produce any specification which will cover the lot. However, I have tried and leave it to you to criticise.

Mr. M. I. D. Mufti (M. E. S.):—I congratulate the author for his very interesting Paper on "Collection of material for and consolidation of water bound macadam."

1. With regard to Collection in stacks, vide page 2 (k), item 1, it is not always practicable to stack the metal outside the road berms.

- (i) In plain sections the metal should normally be stacked on the lower (i.e. outer) berms, leaving the upper berm clear for traffic at all times. On embankments, of course, this is not feasible; this should however always be decided by the Engineer-in-charge.
- (ii) Metal for bridges and through cuttings should be provided by doubling the stacks of the approaches.
- (iii) The best place for collection of metal in hill sections will be against the parapets except on bank or re-entrant corners, where metal will be stacked on the upper side in order not to interfere with the drainage.
- (iv) Metal must be screened and should not be accepted unscreened even on reduced rate.
- (v) It has been found by various experiments that about 11 cubic feet of screenings are obtained per hundred cubic feet of metal.
- (vi) In plain sections, screenings should be stacked behind the metal in stacks of 13 inches height (measured as 1 foot).
- (vii) In hill sections, the screenings stacks are to be 10 feet by 10 feet by 13 inches.

7 (k1)

As regards consolidation of metal the agency and operations should be organised in the following categories :—

1. Preparing and maintaining diversions.
2. Scarifying old road surface.
3. Spreading metal and cambering to template.
4. Providing clay fillets to retain the water.
5. Dry rolling.
6. Watering.
7. Wet rolling.
8. Earthen upper berms; spreading screenings and light rolling
9. Cleaning up lower berms.
10. Painting date of consolidation on inner faces of mile stone.
11. Completing road metal diagrams.

3. A report to be rendered after completion of each mile may be as follows :—

Road	Diamond Harbour Road	Alipore Road
Width of metal.	12 feet	9 feet
Miles consolidated during year.	57	3
Cost of consolidation per cent cubic feet.	Rs. 3/-	Rs. 3/4
Date of commencement.	20th July 1937	3rd Aug. 1937
Date of completion.	8th Aug. 1937	17th Aug. 1937
Whether completion date entered on mile stone.	Yes	Yes

4. As regards the quantity of work or progress, (*vide* para 15 of Paper) I would say that the actual output of the consolidation completed in one working day is about 1000 cubic feet. This gives the following figures :—

Width of Metal ($4\frac{1}{2}$ inches thick)	9 ft.	12 ft.	16 ft.	18 ft.
Running feet per working day	300 ft.	220 ft.	180 ft.	150 ft.
Days per mile including Sundays	20	27	34	40

If two rollers are employed the time will be halved. It should be noted that the full number of labourers per roller must still be employed and it is not normally economical to use two rollers together.

The minimum labour required per roller is as follows :—

	Mates	Coolies	Donkeys
Diversion	...	2	...
Scarifying	1	4	...
Side fillets	...	2	...
Spreading metal and screening	1	8	...
Watering	...	2	...
Berms	1	6	4
Total	3	24	4

Water carts may be provided if considered necessary.

5. As regards diversions (*vide* para 19 of Paper) I would suggest that the length of the diversion should be allowed for 4 day's work, (1 spreading, 1 rolling and 1 setting and 1 extra, *i.e.*, 1200 feet, 900 feet, 675 feet, 600 feet for 9 feet, 12 feet, 16 feet and 18 feet metal width). Barriers and diversions will be moved after a day's task daily.

On hill sections etc. where traffic must go on the upper berms it will be kept on the berms by a line of boulders along the edge of the metal.

6 Regarding Safety Precautions (*vide* para 20 of Paper) it is suggested that in addition to red and green flags a red notice board of 15 inches by 24 inches and 4 feet high marked "Road under repairs" in white letters and surrounded by 12 inches by 12 inches red flag should be erected, 100 yards from the barriers or further away if a blind corner intervenes. White notice boards 15 inches by 24 inches and 4 feet high marked "Diversions" should be erected where diversions take off. At night "Diversion" notice boards will carry white lights and red lights will be fixed to danger signs, barriers and obstructions outside the barriers, *i.e.* metal heaps or rollers. This does not apply to roads that are closed at night.

Mr. W.L. Murrell (Bihar):—If we take the length of water-bound metalled road in India as 60,000 miles, and assume the average width as 9 feet, which is reconsolidated every fifth year with a depth of only 3 inches new metal, then simple arithmetic will show that, even if collection and consolidation cost only Rs. 12/- per hundred cubic feet in all, then India spends annually no less than 170 lakhs of rupees on her ordinary metalled roads, apart from surface-treated road

If this Congress can improve the technique by only one per cent, we will prevent waste of public funds of no less than Rs. 1,70,000/- annually.

(It might here be noted that this figure is about seven times the annual cost of holding this Indian Roads Congress—an expenditure which it is scarcely long-sighted to begrudge).

Viewed in this way, Mr. Trevor-Jones' paper and, indeed, useful discussions on it are at-once seen to be matters of very great importance.

I regret that there are a few points about the paper with which I cannot agree.

The introduction seems to give the impression that Mr. Trevor-Jones' proposed all-India specification is based on the accepted specifications of certain Governments, and on the M.I.S. Handbook, Vol. III.

I must say at once that the proposed all-India specification seems to go directly contra in several important respects to Chapter X of the Handbook, and to the Bihar Specification.* I have not seen any other Provincial Government specification.

A number of copies of the Bihar specification have been distributed among those present here, and the M.E.S. Handbook, Vol. III is readily available.

My chief objection is to the proposed deliberate grading of the metal, to form what a concrete engineer would call a "workable mix".

The M. E. S. Handbook and the Bihar specifications, on the other hand, make for what a concrete engineer would call a "harsh mix", i.e. an inter-locking collection.

Vide pages 148 & 149 of Vol. III of the Handbook (1931) the normal gauge metal must pass through a 2 inches ring but not through one of $1\frac{1}{2}$ inches.

Vide page 1 of the Bihar specification, the Indian Roads Congress specification for broken stone has been adopted to prevent fines and dust from coming into the stacks.

There may be something to say for graded metal in places where basalts and other rocks having minerals of cementing value are used, but in Chota Nagpur there is no such stone.

This graded aggregate proposed by the author of the paper reminds one of the crushed rock collected for road work in Assam and in parts of Australia. More or less altered, or rotten rock, is put through the stone crusher of which the jaws are set to get a certain grading. The crusher run is then spread and consolidated with water. It is sometimes consolidated with a roller, sometimes simply by the traffic. But this type of aggregate is rich in good binders such as altered felspars, and, in any case, such roads are classified more as gravelled than as metalled roads.

Chota Nagpur uses chiefly good vein quartz, many varieties of quartzite, and a few miscellaneous other metamorphosed rocks like epidiorites, generally with no constituent minerals of any cementing value.

Failure on most water-bound macadam roads in Chota Nagpur is by corrugation, and it happens most quickly where bad, brittle, crystalline quartz has been used, i.e. where steam-rolling leads to the quick formation of small stuff and sand. Such a resulting workable mix easily worked up into corrugations by even a small amount of motor traffic.

My next objection is to the cost of the work if done to Mr. Trevor-Jones' proposed All-India Specification.

In Chota Nagpur the P.W.D. now have a number of granulators driven from the road rollers in order to expedite the supply of chips for surface treatment. With close control we might turn out road metal something

* Reproduced as Annex, page 80 (k 1)

similar to the grading advocated by Mr. Trevor-Jones, but the cost of doing so would be at least twice the cost of ordinary road metal.

As we now collect for only 3 inches loose depth or new metal as against the $4\frac{1}{2}$ inches mentioned by Mr. Trevor-Jones, we could not reduce the depth to make savings to meet the increased cost of the graded metal.

With the District Boards, who have no granulators and whose supervision is often inadequate, I do not see how they could collect to anything like the grading required, even if the rate paid were at least three times that of ordinary metal.

There are also a few points in practical procedure which I would like to remark on.

Para 8 of Mr. Trevor-Jones' paper puzzles me. It starts in the same way as the specification in para 2 section 10 on page 152 of the M. E. S. Handbook, which latter says that the object of raking the metal into baskets from the top of the stacks is to free it from fine stuff and dust.

In other words, it would seem that the effect of the proposed All-India Specification would be to leave the fine stuff and filler in the roadside stacks.

As regards hand-packing the bigger pieces (1 inch to $\frac{3}{4}$ inch) below, and the smaller pieces ($\frac{1}{4}$ inch to $\frac{1}{8}$ inch, to say nothing of the filler) on top, this seems impossible unless the two are screened out and the larger stuff is spread first. Experience shows that each time a dry graded mix is handled, the fine stuff tends to go to the bottom and the coarse stuff to remain on the top.

Then Mr. Trevor-Jones, in the same para 8, states that there should be no necessity to withhold any metal for rectification.

In Bihar we are most particular about this very point, as will be seen under para 7 (b) of the Bihar specification. It seems to us that everything humanly possible should be done to prevent the pitching of motor vehicles, so as to give more comfort to motorists and in order to decrease damage to the road.

On yet another point I am somewhat disappointed that Mr. Trevor-Jones disregards the Chota Nagpur practice of salvage edging described in para 5 (b) of the Bihar specification. By this practice we have been converting 9 feet width of metal surface into what is, to all intents and purposes, a 10 feet 6 inches width, and this practically without any additional expenditure. This is a great gain in these days of fast traffic.

To conclude, it is at least apparent that, while standardization of practice is our common goal, one specification cannot possibly cover the whole of India.

Not only does road metal vary so greatly in its characteristics, but the climate and locality will decide whether the water-bound consolidation is to be done in the dry weather, as in the Punjab, or during the monsoon, as in Bihar.

It is hoped that various specifications for water-bound macadam will be tried out on the Test Track; but in this connection I must say that, so far as water-bound macadam surfaces are concerned, it is useless to do any testing with wheels that are simply dragged round the track. The wheel must be self-driving, and the ratio of the unsprung load to the total load must approximate to that found in the average motor vehicle. This equipment would be very expensive, however, and it is doubtful whether funds could be found for it.

I would suggest that a few points might be adopted from the Bihar specification when the sets of All-India specifications are being drafted.

I cannot close my remarks without expressing thanks to the author for his excellent paper. If we can get out sets of standard specifications for water-bound macadam to cover varying conditions, the tax-payer will be greatly indebted to Mr. Trevor-Jones for having set the ball rolling.

Mr. Brij Mohan Lall (Punjab) :—Mr. Trevor-Jones should be thanked for producing standard specifications for collection of materials for and consolidation of water-bound macadam, which is, and will for ever remain, the basic foundation of all roadwork in the country. The existing specifications for the work, however, differ from province to province, and standardization in this respect is indicated to involve as far as possible a uniform practice in all the provinces. The specifications drafted by the author are quite suitable except in some minor details. Some amendments are suggested in the following note.

In para 1, Collection of materials, it has been suggested that in hill sections metal should be stacked on special platforms or sidings located off the roadway at suitable intervals say two furlongs. In actual practice such a procedure will be found to be very expensive. To provide only four platforms in one mile for stacking about 20,000 cubic feet of metal, that is ordinarily required for one mile, will require, each of them, to be about 5000 square feet in area. Such a large level space is very difficult to obtain in a hilly country except at a prohibitive cost. It is therefore suggested that this sentence be amended as follows:— "In hill sections, metal should be stacked at places where it is likely to cause least hindrance to traffic at the discretion of the officer-in-charge".

Design of water-bound macadam.—I agree with the author that a lighter thickness than $4\frac{1}{2}$ inches should be sufficient for water-bound macadam when the surface is to be water-proofed. A 3-inch thickness of suitably graded material should meet the requirements, in my opinion. The grading suggested by him on page 3(k), however, appears to contain too much of fine material. The biggest size of stone suggested by him is one inch which is smaller than what is used even as aggregate in a cement concrete mix for roads.

Moreover the mixture suggested by the author will be too expensive. A 3-inch thickness of such a mixture would cost more than even a $4\frac{1}{2}$ inches thickness of the 2 inch uniform metal now commonly used. The following grading will probably be found suitable, and will not cost much more :—

2 inch to $1\frac{1}{2}$ inch	50 per cent
$1\frac{1}{2}$ inch to 1 inch	25 per cent
1 inch to $\frac{3}{4}$ inch	20 per cent
under $\frac{3}{4}$ inch	5 per cent

In addition to the above material, which will be initially laid for consolidation, about 5 to 10 per cent of bajri under $\frac{3}{4}$ inch will be required for the purpose of binding or blinding referred to in para 12 of the paper.

Para 4 of Paper—Surface Scoring.—For resurfacing of old metalling a better job is likely to be obtained if the whole surface is scarified to about 2 inches thickness, and the scarified material relaid to proper camber after screening off dust. This method provides a better key than the mere scoring of the old road surface. This, however, is not recommended when the crust of the existing metal is too thin. In the footnote to para 4 a doubt has been expressed with regard to the efficiency of providing a thin layer of earth under the new metal to act as a cushion and to work up between interstices of metal. In case of construction of new roads where the soling is of bricks, brick metal or stone, this procedure has been found very useful in providing a bond between the soling and the wearing coat, and in binding the new metal from the bottom. In case of remetalling or where the soling coat is of kankar, the layer of earth is not, however, necessary. It is suggested that para 4 be amended as below :—

4. Preparation of sub-grade.—(a) New Metalling—The soling coat should be laid and rolled to the specified thickness and camber, and, unless it is of kankar, should be covered with a one-inch layer of earth to act as a cushion, and to work up between interstices of metal to provide an adequate bond.

(b) Remetalling.—The old wearing surface, unless the crust is too thin, should be scarified to a thickness of about 2 inches. The scarified metal should be relaid to the specified camber after screening off dust, and lightly rolled. If, however, the existing crust is too thin to be scarified, the whole surface should be scored with lines about $1\frac{1}{2}$ inch deep and about 2 inches apart in order to provide a key. Deep pot-holes should be patched up.

Para 5 of paper—Edging or Bands —The first part of the first sentence of the para is suggested to be amended as below :—

"When the sub-grade has been prepared in accordance with para 4".

Para 9 of paper—Templates —As the maximum super-elevation suggested in para 10—"Super-elevation" in paper on Layout of Roads is 1 in 12, templates for cross-slopes $1/7$ and $1/10$ are unnecessary. They should therefore be of cross-slopes $1/12$, $1/16$, $1/18$ and $1/20$.

Para 12 of paper—Bajri Binding or Blinding.—In the last two sentences of this para it has been suggested that the surface should be well rolled and watered to such an extent that the blinding material is formed into a slurry. The amount of watering suggested here is excessive, and is likely to spoil the consolidation. Watering should only be done to such an extent that the blinding material gets into the voids of the metal. It has also been suggested in this paper that not more than one furlong should be under operation in any one mile at one and the same time. This appears too low

a limit. In para 15 of the paper 3000 to 4000 square feet has been suggested as one day's progress for one steam roller which is equivalent to 250 feet to 333 feet of a 12 feet wide road. Therefore, if each operation *viz.* scarifying preparation of sub-grade, spreading metal and consolidation is carried out for a length of 250 feet to 300 feet, the total length under operation cannot be less than two furlongs, if satisfactory and continuous progress of work is to be obtained. This limit should therefore be raised to 2 furlongs.

The paper does not include any specification for the soling coat. It is suggested that a suitable standard should also be laid for thickness and consolidation of the soling coat. Hitherto it has been a practice to provide a $4\frac{1}{2}$ to 8 inches thickness of brick, kankar or stone for soling coat; this, however, appears to be on the higher side. Recently in the Punjab, experiments have been made on a large scale in widening existing roads by providing a soling coat of only three inches thickness of overburnt brick metal, or omitting it altogether where the berms were too hard, and have proved successful. This aspect of the problem deserves further consideration at this Congress.

Rai Sahib Fateh Chand (United Provinces):—I congratulate Mr. R. Trevor-Jones for bringing forward this useful Paper. The work of collection of material and consolidation of water-bound macadam is common and is largely done in almost every part of India. Yet the specifications available on the subject differ so much from each other that it is a puzzle to the engineers as to which to follow, in the absence of any standard specification from the Indian Roads Congress.

I suggest the following points to be considered in connection with the above paper :—

1. **Collection:**—The stacks should be continuous and of uniform section which should be the same as required by calculation for the width of the road to be renewed, so that the total length of the stack for each mile should be 5,280 feet. Gaps should be left not only for drainage but also at all points where the road width does not permit of stacks being made on the road-side without causing obstruction to road traffic. An equal length of stacks for such gaps should be made by laying a double line of stacks along the road nearest to the gaps taking care that no stack is laid within 10 feet of the edge of the metalled portion. The bed of the stacks should be properly levelled and passed by the overseer-in-charge before stacking is done to avoid the common trick by contractors of taking advantage of central high portions of the ground in stacking.

2. **Measurements:**—In the case of stone-metal, stacks should be made only 12 inches in height which should be measured as 1 foot, as per United Provinces Public Works Department's specifications. Stacking should not be allowed piece-meal. It should be started only after the whole material, required for each mile, has reached the road-side and should be completed within 10 days. The overseer-in-charge should see, while stacking is in progress, that the stacks are made of full size. The work should be measured, checked and passed within a fortnight of the contractor's or subordinate's report about the work of stacking having been completed and the contractor should be bound to accept the measurements found to exist

at the time of checking by the officer authorized to pass the measurements. If no checking is done within a fortnight of stacking, the checking officer might get a portion of the stack broken up and the metal thereof restacked and in such cases the measurement of the newly made stacks should be accepted by the contractor. An addition of some such provision as suggested above is required to prevent disputes in measurements to avoid which something should be done by laying down the method of checking measurements in cases where the stacks lose their original size and shape due to lapse of time or some other such cause.

3. Thickness of Coat:—The usual thickness of the renewal coat should be $4\frac{1}{2}$ inches. If, however the base consists of more than six inches of road metal the thickness of the new coat might be reduced to 3 inches only so that the total thickness of the metal old and new shall not be less than 9 inches but the surface of the old metal should be scarified or wholly picked up to a depth of $1\frac{1}{2}$ inches at least, so that there shall be a total thickness of $4\frac{1}{2}$ inches of the loose metal to be consolidated. If the thickness of the layer is less than this or if it is uneven, that is, somewhere it is less than $4\frac{1}{2}$ inches and somewhere more, the surface is bound to break up very soon. To avoid this the old surface must be brought to template after being scarified.

4. Grading:—This is a very important matter and there is great divergence of opinion on it. I consider the following proportion to be most suitable for water-bound macadam:—

1 inch to $1\frac{1}{2}$ inches gauge	30 per cent
$\frac{3}{4}$ inch to 1 inch gauge	50 per cent.
$\frac{1}{2}$ inch to $\frac{3}{4}$ inch gauge	20 per cent.

5. Scoring:—If the road surface is undulating, the whole surface must be scored up and brought to template. If there are ruts on the old surface, the central edge and the higher edges of the road should be scored up so as to fill up the ruts. If the surface is neither rutted nor badly out of template then the scoring might be done in lines at 45 degrees to the line drawn across the width of the road. These lines should usually be 6 inches apart but not more than 9 inches in any case

6. "Daulas":—Care should be taken that "daulas" are laid correctly over the edge of the road in straight lines or in the curve of the road by means of guide strings. Where the road *patries* are lower than the metalled portion, the width of the "daula" should be 3 feet at least to prevent displacement of the road metal under the pressure of the roller. The inner edge of the "daula" should be made vertical and not sloping as is usual with the labourers. The distance between the inner edges of the "daulas" may be 3 inches less than the actual width of the road which will, after consolidation, be found to be equal to the width of the road.

7. Camber:—It should be the same as suggested in my Note in connection with Paper No K (II).

8. Spreading:—Some metal should be withheld for levelling the patches noticed during the course of consolidation which are inevitable on bad

surface. Old patches should be roughly repaired as the metal is bound to sink and patches are sure to form if this is not done properly before spreading new metal. Hand-packing should be carefully done.

9. Blinding:—This might be done with local sand instead of shingle but not with ordinary earth.

10. Progress:—This should depend on the quality of metal used, labour, water and on the type of roller used.

11. Berms:—Earthwork done on berms should be paid at L. S. rates. Earth should be taken from drains neatly arranged near the road boundary. Road crossings should be properly dressed upto a distance of 1 chain on either side of the road.

12. Prevention of ruts:—Earth, brick-bats, broken stone or *kanker* but not boulders might be used for diversion of traffic to bring into use every portion of the road width instead of using the track formed by the first cart tending to form ruts at these places.

13. Watering after consolidation:—It is very necessary that the surface should be kept well watered for at least one week after consolidation.

Mr. G. B. Vaswani, (Karachi):—If these specifications are meant to suit rural and urban roads, a few changes are required to be made.

In the item "Collection of Metal", the word "continuous stacks" may be changed to "stacks of suitable length".

The following are the disadvantages of continuous stacks:—

- (a) They do not provide crossings for the cattle and for the farmers to carry their produce. The cattle will, therefore, spoil the profile of stacks before they are measured.
- (b) Continuous stacks are advantageous for the contractor and not for the Engineer. The Contractor will place his template over the stacks at a few places, thereby proving his honesty that the whole length of stack is to the template, but actually intermediate portions may not be correct to the template.
- (c) There is always the possibility of making a mistake of a tape length in recording the lengths of continuous stacks.
- (d) For checking purposes small stacks are easier than long ones.

As regards making of stacks absolutely clear of the road formation, it is not possible in cities, where not more than half the road width is to be blocked at a time.

I do not agree that $4\frac{1}{2}$ inches thickness of metal is heavier than necessary, particularly if the surface is to be painted.

If the road is to be waterproofed by surface painting, you provide only $\frac{1}{2}$ inch thickness of layer. In that case all the loads are carried by water-bound road. Any reduction in thickness of metal will result in breaking the road surface and causing pot-holes.

Size.—As regards size of metal, I am not in favour of using smaller size than 2 inches. In case of soft metal the size may safely be increased to $2\frac{1}{2}$ inches.

Soft metal of small size will break and be crushed into powder under roller before proper consolidation is completed. Hard stone is not obtainable in all parts of India. Local stone has therefore, to be utilized.

Grading.—If the grading of metal, as suggested by the author on page 3 (k), is adopted, it may look all right theoretically, but in practice the contractor will supply you more of dust and chippings than the graded metal required. I would rather insist that the contractor should stack 2 inches size of metal separately, so that one is sure of getting proper size of metal. He should collect screenings in separate stacks.

Spreading.—The larger size of metal should be spread first to proper levels and then consolidation should be started. When the metal has been well consolidated, small chips should be spread to fill up voids and then further consolidation should be continued till no sign of movement in the metal is observed. After this, blinding (sand and *mooram*) may be spread in a thin layer to fill up the interstices.

A thick layer of the blinding material helps in covering defects of a bad road.

Mr. M. Mahapatra (Cuttack):—I would like to make the following suggestions :—

1. **Collection in Stacks.**—It is not convenient to have continuous stacks on the road-side land outside the berms. Collection in standardised stacks of, say, 20 feet by $\frac{7 \times 3}{2}$ feet by 2 feet size will be better.

2. **Measurements.**—The procedure mentioned by the author is adopted in some places, but the better method would be to calculate the required quantity of loose material for a certain thickness of renewal and measure the collection in standard stacks without giving any allowance for loose quantity. 'Formas' or 'gauges' should be constructed accordingly with steel plate linings and be checked periodically.

3. **General.**—As the currency of maintenance estimates expires in the month of June and as the best season for collection is from November to May, metal required for consolidation and patch repairs during the period July to November is to be collected by the end of April preceding.

For the sake of convenience collection and consolidation should be carried out by full furlongs instead of miles as stated in the paper.

Design.—For a B class water-bound macadam road at least 3 inches thickness of metalling is necessary if the sub-grade is smooth and 6 inches over new soling, and for such thickness hard granite metal of the size stated below has been found to give satisfactory results :

2	inches to	$1\frac{1}{2}$	inches	gauge	...	10	per cent.
$1\frac{1}{2}$	inches to	1	inch	gauge	...	75	per cent.
1	inch to	$\frac{3}{4}$	inch	gauge	...	10	per cent.
$\frac{3}{4}$	inch to	$\frac{1}{2}$	inch	gauge	...	5	per cent.

4. Surface scoring.—The full width of the road to be renewed should be picked to a depth of 3 inches or so, and the old layer of metal should be completely removed. Then the surface is to be rolled once and using clean well-sorted old metal, proper camber is to be formed. For super-elevation of about 6 inches, the outer half of the road will have only line picking and then to be formed to required slope with the metal removed from the inner half.

5. Edging bunds or "Daulas".—In practice these bunds do not serve their purpose well. These are damaged by rolling the edges and, even when properly maintained, do not show the condition of the road as formed during the process of consolidation and necessitate frequent use of the template to check the camber. The better method is to re-form the low berms prior to consolidation and allow the water to flow from the road surface to a sump either in the side drain or berm whichever be convenient and to re-use the muddy water thus collected. Any damages caused to the drain or berm during the process of consolidation should be made good as soon as the rolling is over.

6. Camber.—It is always on the safe side to give a bit steeper slope especially in water-bound roads of the locality subjected to heavy rainfall. Cambers of 1 in 48 and 1 in 24 to 1 in 30 in tar-surfaced and water-bound macadam roads respectively are giving satisfactory results.

7. Super-elevation.—In giving super-elevation care should be taken not to change the main gradient of the road. Centre of the road should continue to have the same longitudinal gradient and necessary amount of cross slope should be given by raising the outer edge and lowering the inner edge. In curves of radius less than 500 feet, super-elevation should be limited to 1 in 20 and it is to be seen that any section of the road must have some sort of cross slope, either camber or super-elevation.

8. Spreading metal.—Generally a proper camber is not obtained in one spreading. During the process of consolidation, even when the edges are protected from sliding, numerous waves and depressions are formed, and for mending those, at least 5 per cent of small size metal is necessary.

10. Level.—By fixing a plumb-bob to the template, level of the edges metalling can simultaneously be checked along with the camber.

11. Rolling and consolidation.—Rolling without water crushes the corners of metal and weakens the consolidation. Hence water should be sprinkled over the spread metal before commencing the first rolling.

12. Bajri, Binding or Blinding.—For proper consolidation certain percentage of clay is necessary. Red gravel consisting of pebbles $\frac{1}{2}$ inch to $\frac{1}{16}$ inch size with a mixture of fine particles and red earth to the extent of 10 per cent forms a good binding material. If the gravel contains a higher percentage of clay the quality can be improved by adding sand. Blinding material should not be spread in thick layers. Spreading should be in several thin layers well watered and brushed till the interstices are completely filled in. Watering and brushing should be continued throughout the process of consolidation which will be considered as complete when water does not go into the metalled surface but can be seen moving with the roller. Imme-

diately after water-rolling, if the road is to be opened to traffic, the new consolidation should have a sand blinding of $\frac{1}{4}$ inch thickness to give a non-sticky surface. As soon as the road surface is a bit dry, which it generally gets on the next day, the surface should be rolled once again.

13. **Bajri, measurements not to be added.**—As the quantity of blinding material differs for different sizes of the metal, amount of rolling, and quantity of water used, it would be reasonable to measure the quantity and pay for it separately. The rate of consolidation should be exclusive of the cost of materials, otherwise there will be the difficulty of stacking advance collection to be used up in the succeeding rains.

15. **Progress**—If water load does not exceed 400 feet, 2000 square feet of 3 inch thick hard granite surface in hill sections or 3200 square feet in plains can be completed in a day with an 8 ton Road Roller. Picking, spreading and consolidation each should proceed one day in advance of the following operation, that is, if the daily average of consolidation is 220 feet, picking of 200 feet with an equal length of spreading of new metal, may be permitted on the same day when the first 220 feet of the road is under consolidation. In hill sections, where there is no possibility of diversion, loose metal should not be left on the road surface at the end of a day's work. Any portion picked up should be thoroughly cleaned of old metal and any new metal spread should be rolled and surfaced with a layer of gravel for water-rolling to be done on the following day.

16. **Completed Work.—Watering and Maintaining.**—One week's watering may be sufficient if the road is closed to traffic. But for the roads to be used immediately after consolidation is over, the minimum period of watering should be 2 weeks. The completed work is to be maintained by the contractor for 3 months by blinding with gravel at an interval of 15 days or shorter period as the conditions require and removing other defects which may appear during the above period.

17. **Making-up Berms.**—Making up berms should be done in advance of consolidation. But in cases where this cannot be done, due to some reason or another, both consolidation and re-forming berms should go on side by side. The borrow-pits should have diagonal 'thondoo's and be so located that those can be easily drained.

18. **Profile of berms and sides.**—At super-elevations, the side berms should be in the same continuous cross slope as the metalled portion.

Mr. Syed Arifuddin (Hyderabad-Deccan):—Many of our engineers probably remember by heart the specifications relating to collections of material and consolidation of water-bound macadam. On principal points we all practically agree, differences will be of minor nature and the compilation of the specifications can be left to the Technical Committee. There are just three points on which I would like to say something:—

1. **Collection in stacks.**—There should be a fixed number of stacks per furlong and these should be of uniform dimensions; the height should be more than 1 foot preferably $1\frac{1}{2}$ to 2 feet. Sectional area should be a convenient number, say 10 or 15 square feet. There is no harm if one

stack in each furlong differs in length from others to make up the required quantity. There are two objections in my mind to one continuous stack.

- (a) The width on the top is very small and the section gets disturbed very soon on account of which the checking becomes very difficult. This will induce the labour to rob the material without being detected.
- (b) The height is to be kept too low. The small height has this disadvantage in the case of metal of $1\frac{1}{2}$ inches gauge that it increases the possibility of error in measurement.

2. It is rather difficult to obtain grading of definite percentage even if we allow 10 per cent variation. Unless by actual test the advantage is proved to be so great as to justify the extra expenses, I do not think it should become a general practice. In the Code of Practice it is better to specify two proportions, one which is easily obtained and the other which is specially graded, mentioning the works where it can justifiably be used. The usual practice is to use $1\frac{1}{2}$ -inch gauge metal. It may be specified whether the gauge should be "Circular" or "Square" one, and also whether the stone should pass through in all directions or it is enough if it passes through in any one direction. I think where hard stone is not available and we are obliged to have soft material, 2 inch gauge stone may be permitted.

3. In connection with rolling the metal, it will be better if the Engineers make experiments on the number of times the roller has to pass over the road, dry and wet, in order to consolidate it sufficiently and send the result to the Technical Committee. It will be useful if this is also incorporated in the specifications for guidance.

Mr. K. E. L. Pennell (Chairman):—I do not think we have time to finish off now. If any other member wishes to speak on this subject he may do so after lunch.

(Continued at 2-30 p m after lunch)

Mr. Dildar Hosain (Hyderabad-Deccan):—The author has rendered a great service to the Congress by bringing about discussion on the subject of such fundamental importance as the Layout of Roads, and Collection and Consolidation of water-bound macadam. It need scarcely be emphasised that water-bound macadam road is going to have an unassailable position, for a long time to come in the scheme of road construction in India.

I may, however, draw his attention to the fact that if the Code of Practice is to be made applicable to all-India, it should cover the requirements of the different provinces. There is another point, viz. that the paper has been written primarily with a view to reconstructing road surfaces but if it is going to apply to new surfaces, I mean new constructions also, provision has to be made in regard to the consolidation of a coat of metal as far as 6 inches thick.

I shall now pass on to a few points:—

Measurements —It is stated that the metal stacks should be 13 inches high but measured as one foot. It is also stated in the preceding para that the

stacks should be continuous. The practice in different parts of India with regard to the height of stacks is probably different. As far as I am aware, there is no standard height and consequently the size of the stack. For the stacks to be continuous and one foot high, the size of the stack will have to vary according to the thickness of the metal coat proposed to be laid. In many cases, for several practical reasons, it is generally not possible to resort to continuous stacking. If, on the other hand, the stacks are not continuous, but laid in different sizes and in a haphazard manner, the time spent in checking the measurements and the arithmetical calculation is considerable.

I would therefore suggest that instead of one foot standard height, it would be of practical utility if the size of the stack is standardized. For several reasons such as economy of space etc., it would be preferable to fix the height of the stack as $1\frac{1}{2}$ feet. By fixing the size of the stack, the number of stacks per furlong can also be fixed. This would facilitate checking and save time in calculations.

I may explain this by taking a concrete example. Taking a 3 inches coat of metal—

The quantity required for a 12 feet width of road surface

$$= 5280 \times 12 \times \frac{3}{1} = 15,840 \text{ c.ft.}$$

$$\therefore \text{Quantity required per furlong} = 1,980 \text{ c.ft.}$$

$$\text{If 'n' or the number of stacks is 20, Q per stack} = 99 \text{ c.ft.}$$

$$\text{Let Height, h be } \frac{3}{2} \text{ feet.}$$

$$\text{Then A or the area of each stack} = 66 \text{ square feet.}$$

This means that the average size of the stack will be 11 feet by 6 feet.

If the thickness of the metal coat is $4\frac{1}{2}$ inches, the number of stacks will have to be 30 per furlong and if 6 inches, it will be 40.

Even if the height of $1\frac{1}{2}$ feet is not agreed to, the size of 11 feet by 6 feet by 1 foot, lends itself for practical use, as then the number per furlong will only have to be increased from 20 to 30. So, whatever height is finally approved by the Congress, the size of the stack is, in my opinion, an important point to be decided.

In actual practice, the top dimensions of the stack will have to be $9\frac{1}{2}$ feet by $4\frac{1}{2}$ feet in the case of $1\frac{1}{2}$ feet height, and 10 feet by 5 feet for 1 foot height. It is assumed in these cases that the angle of repose of metal is 45 degrees.

Another point in favour of non-continuous stacks is the recommendation for graded metal made in the top para on page 3(k). I am inclined to think that instead of making an assortment of different grades in one stack, it would be better to have separate stacks for the different grades of metal.

Design.—It is not clear how the metal coat of $4\frac{1}{2}$ inches thickness is said to be usual in India to specify. The thickness is usually 6 inches on an average. Renewal of the surface is done according to the actual wear

that takes place in a metal surface. Thus, if the wear has been 3 inches, the reconstruction is specified to be 3 inches, although on actual compaction and consolidation, it is more than 3 inches in the centre and less at the sides.

It is stated that working by this method a thick coat of metal is a necessity since consolidation of a thin coat cannot be effected. It would be useful to define the limit between a thin and a thick coat.

With regard to the grading of the metal, it is seen that the maximum size of metal is now presented to be 1 inch, whereas the limit of the size now generally prevalent is $1\frac{1}{2}$ inches. Reduction in the size and the introduction of the proposed grading would mean that the rate for metal collection will have to be revised. However, while there can be no disagreement about the importance of grading, a more suitable grading would be:—

$1\frac{1}{2}$ inches	to	1 inch	...	50	per cent.
1 inch	to	$\frac{1}{2}$ inch	...	25	per cent.
$\frac{1}{2}$ inch and below			...	25	per cent.

Surface scoring.—The work of cutting ridges and using the material or filling ruts appears to be uncalled for. Merely filling the old metal into the ruts without scoring the surface will not produce the bond which is necessary. A proper plan would be to pick the entire surface to a depth of $1\frac{1}{2}$ inches and to spread the old metal uniformly. Over this the new coat of metal should be spread to a proper camber.

If picking is done in bands 12 inches apart, it will still leave strips in between, which will have no bond for the new coat of metal.

In the case of some of the roads with muram surface, which were metallised it was found that picking the surface on the strip method (after thoroughly watering the surface) but with strips at 45 degrees, gave much better results than the usual process. Longitudinal strips have also the tendency of introducing corrugations in the metal surface.

Camber.—It is necessary to specify that before spreading a new coat of metal, the sub-grade should be formed to a proper camber so as to provide a uniform thickness of metal coat. Otherwise, the thickness of metal would be more at the crown and less at the edges.

The reference of 1/7, 1/10, 1/15 and 1/20 for camber templates needs elucidation.

Blindage.—The process of consolidation is said to be complete with the spreading and the consolidation of blindage. It would be desirable if a minimum thickness of blindage is laid down in order that there may be neither more nor less than necessary use of this material.

The practice in Hyderabad is to have a muram blindage of $\frac{1}{2}$ inch thickness. After this is consolidated, another $\frac{1}{2}$ inch coat of sand, called 'topping', is spread while the blinded surface is still wet. This has given very satisfactory results.

The Paper does not mention the width of the road surface to be taken up for consolidation. Opinions differ on this point, some being in favour of

half width and some in favour of full width to be taken up at a time. It may however be mentioned that if the width to be consolidated is 12 feet, it is desirable to take up full width, as otherwise the width of the roller will not fully cover the half metal width.

Mr. T. Lokanathan (Coimbatore):—This is certainly a strikingly common but nevertheless highly important subject. Some of our friends have voted for five minutes to each speaker instead of ten minutes proposed by the Chairman. This shows that we are feeling somewhat disgusted about the old stale water-bound macadam. Perhaps it is not really disgust but a feeling that nothing more has been or could be done to improve water-bound macadam. Ever since I entered service, for the past 18 years I have been Road Engineer, making new roads and maintaining the old. I have been facing the problem I still meet to day. With the advent of heavy motor traffic and increasing volume of cart traffic, it is heart-rending to see the road-surface going into wheel tracks and pot-holes. Our ideal has not been achieved. Not that we have been dull or reluctant; we have been at the problem and have not solved it.

This year I tried the use of lime kankar for blinding the water-bound granite. By lime kankar I mean the nodular stuff of size between $\frac{1}{2}$ inch to 1 inch. This sort of thing is available at even shorter leads than the usual gravel we have been using and which is really mere earth for 70 per cent or something like that. We do not want the metal to move about in a consolidated surface. We want it to remain in place and avoid attrition but we had not been successful in avoiding attrition so long as we used the earthy gravel. When we use nodular *kankar* and do careful consolidation, the granite metal stays in position as in a sort of concrete, the surface is smooth and compact without tendency to unravel. The surface does not become very dusty; by the way, it serves also as an antitubercular measure. The white surface which we get affords greater reflectivity to motor car lights at night.

I do not like super-elevation on water-bound granite-macadam. It would be nice to do it on tar and concrete surfaces; if done on water-bound macadam, the surface unravels; and neither the motorist nor cartman will thank us for it.

For a day's work with power-roller, about two-thirds of a furlong for remetalling twelve feet wide and three inches thick will do.

I do not know what researches you have made for the quantity of water required for water-bound consolidation. I took some statistics and found that in very dry areas about 75 percent of the quantity of metal and in others 50 percent would be alright.

Mr. Dildar Hosain referred to the Madras practice in control on contractors and wished to know how it was done. It is done by the simple expedient of keeping back final bills for three months after the consolidation is done; if in that period anything goes wrong with the surface the contractor has to rectify the defect.

After once the consolidation is done well avoiding attrition of metal, when wheel tracks start forming due to wear under the steel tyre of the cart, we close the wheel tracks with new metal and keep the surface to

proper camber. Frequent blinding is also useful to maintain the surface free from tracks and unravelling. I think some gentleman said that blinding of the surface is really 'Blinding' which serves to hide the bad condition of the surface. It is not so. Frequent blinding serves to keep the stones in position and I have shown to some friends that whether blinded or not, dust arises out of macadam as the pneumatic tyre of the fast motor car is not wanting in resource to suck out dust even from an unblinded surface.

Mr. S. A. Amir, (Bihar):—It is not my intention to either criticise or suggest any improvement on the specification put forth by the author of this paper. I believe it will be of interest to the members to know if any work according to this specification has actually been carried out and if so how the result compares with the usual work done with 2 inches metal as specified by Indian Road Congress. If any figure of the actual or probable cost of consolidation with the size and grading of metal as suggested by the author could be given compared to what it usually is for the common method of consolidation for the same locality this will also be useful in coming to any conclusion regarding the practicability of specification recommended by the author. I hope the author will please enlighten us on these points.

Mr. H. Hughes (Rangoon):—In Para 2, "Measurements," the author advocates counting 13 inches height as one foot. I dislike this idea very much. The author suggests that the 13th inch is to allow for loose stacking. It is well-known that by filling the stone measuring box from different heights different results in the quantity can be obtained; so the false unit of height seems hardly the way to get over the difficulty about loose stacking. If it is necessary to be very precise, the Specification could state the height from which the stone was to be poured into the box but in practice it is sufficient to see that the stone is poured in from a reasonable height. It has been urged that the 13 inches height takes account of the voids in the stacks of stone but the voids in the stacks are very much greater and moreover the voids in different size of stone vary. It has also been urged that 1 inch extra height provides for the amount lost on compaction. That again is incorrect. So it seems that the false unit is not based on any scientific data, and the length of time that it has been in force need not cause it to be regarded with sanctity or its abolition with regret.

In Para 6, Camber the author has used the word "camber" in the sense of side slope; the Congress should lay down the definition for "camber". In the Specification* which has been handed round just now, a definition has been given, but it seems to make matters more confusing. The American definition of camber is total rise over total width which seems logical.

Mr. B. S. Puri (Central P. W. D.):—I would like to say a few words about the Road chart which we found very useful in Burma. This chart gives the thickness of metalling (soling and metalling) in different furlongs of different miles of a road. Copies of this chart used to be hung in office rooms of the Executive Engineers and Sub-Divisional Officers.

The existing thickness of metalling in a particular mile is a very important factor in determining the most economical thickness of the renewal coat of metal. Some gentlemen have advocated a renewal coat of $4\frac{1}{2}$ inches, others have advocated a renewal coat of 3 inches; yet another gentleman has

*Vide Annex, page 30 (k 1).

advocated a renewal coat of 6 inches. We found that where the thickness of the metal over the soling was more than 6 inches it was enough to scarify the road crust to a thickness of 3 inches, screen the scarified metal, lay bigger stuff on the road, and add about 2 inches of new stone metal on the top. The screenings could be used as filling in the interstices of stone metal after partial consolidation and for spreading over the berms.

This chart also prevents the thickness of metalling becoming so great that it may become dangerous for bridges. I remember a case where, by following the rule of renewal coat of $4\frac{1}{2}$ inches every three year, the dead load of metalling over the bridge slab became so great that the bridge collapsed.

In some cases, after taking the borings on the road and preparing the chart, we found that the actual thickness of metal in some miles was as much as 15 inches to 20 inches. We scarified such metal to a depth of 6 inches, and used the scarified material for widening the road.

Mr. R. A. Fitzherbert (Bombay):—On page 3 (k) paragraph 4 below the para a note appears to the effect that "In certain localities it is customary to place $\frac{1}{2}$ inch layer of earth or murum to act as a cushion and to work up between the interstices....."

This method has been used in England when doing grouting to reduce the amount of bitumen or tar used and I actually saw it being adopted for grouting with Colas.

By watering and rolling, the blindage below the metal is worked up to fill the interstices of the metal to the requisite extent; by this method they obtain a semi-grout or even less; the amount of bitumen or tar can be reduced to a minimum.

I think this method is worth trying.

Mr. A. K. Datta (Calcutta):—I shall say just a few words about item 14 at page. 4 (k) on Admixture of clay. We find in Bengal where we mostly used these Jhama bricks, a little admixture of clay was found very efficient; we got better binding. It will be very interesting, at least to me and to you also, to know if we add a little lime with the clay, will that be effective in any way? It will not; but if we mix up this lime and clay and burn the same and powder the burnt stuff, we shall get a cement which we may call Village Cement or a faked cement if we call it, and that will produce with good ballast a first class concrete road. I have got data for village cement made by mixing in my own small laboratory about two parts of lime and one part of earth and burning the same in kilns. According to tension tests with 3 parts of standard sand and one part of this cement, I found tensile strength of 375 pounds per square inch. Where I mixed up 25 percent of cement with 75 percent of the village cement, I got a tensile strength of 680 pounds per square inch with 3 : 1 mortar in one month 18 days. This is really very interesting. The admixture of earth does not pay but if we burn the clay with lime in villages then we can get a stuff which contains the strength. Such material we can develop in villages where some lime stone and some clay are always available, and in such cases the combination of these two with stone ballast and sand will produce a strong concrete road. If we do not call it, cement concrete, we can call it village cement concrete which will rival, if not

cement concrete but very nearly cement concrete. It will be outside my talk here, because it will go outside the domain of this paper if I go further with some of the experiments on a new cement. If members be interested, *I shall say something about this new subject in a paper in the next Roads Congress.* It is superior to ordinary Portland cement, but cheaper in cost.

Mr. Trevor-Jones (Author):—There has been so much discussion that it is quite impossible for me to reply in detail, but I will try to do what is possible in the time at my disposal. I am however much encouraged and grateful for the interest which my paper has aroused. It would appear that something of the sort is really needed as suggested by Mr. Murrell and zone specification is the ideal, if variations in climatic conditions, materials, etc. are to be satisfactorily catered for.

Mr. Hughes of Burma has asked why the 13 inches to measure 1 feet has been adopted to cover voids etc. in stacks. My only answer is that from times immemorial, as far as I know, the 13 inches method has been adopted. It should be possible, certainly, to evolve more scientific methods and no doubt suggestions made towards this end will have due consideration. I think I have made an error in introducing this "Note on the design of water-bound," as it should really find a place in a chapter on "Road Design" which I mentioned in summing up my last paper. The Note in question was taken word for word from Lt.-Col. Whakeley's "Road Construction and Maintenance in India" being Engineer-in-Chief's Technical Paper No. 10, M.E.S. The grading given there is obviously merely an example and nothing else and cannot possibly have universal application.

I have been accused of inconsistency in one place and I think correctly. In the note below para 4, I have stated that the efficacy of a layer of earth to fill up interstices placed below new metal is doubtful, whilst in the "Note on Design" it is stated that the voids are filled with clay and stone dust which should be forced up from underneath. Recently in the Punjab we have been using earth on the top of soling and allowing it to be forced up into the interstices by capillary action of water and it has proved as far as I know, efficacious. It is for consideration whether such a specification should or should not be universally advocated.

Mr. K. E. L. Pennell (Chairman):—I think we are all very indebted to Mr. Trevor-Jones for his very interesting paper and to those members who have given us their views.

CORRESPONDENCE.

1. Comments by Colonel G. E. Sopwith (Calcutta).

In the preface it is stated that the subject matter and data have been obtained from Local Government's specifications from all over India. On page 4 (k), I notice the term "*bajri*" is used. I suggest that, in any Code that may be provided that term be not used. I myself am a Punjabi and a Pathan, and have all my life in India been familiar with this term, but in Madras, for instance, it is quite unknown and would not be understood, as I have found,

Incidentally in Madras small nodules of soft laterite are included in the general term "gravel" and not to know this is apt to lead to unexpected results, as again, I have in my recent ignorance found out.

Page 3 (k). The practice of placing a handful of earth or moorum to act as a cushion is described as being of doubtful value. Without in any way suggesting that that method is really sound I do think that it is of vital importance to produce some foolproof method of filling the lower voids between metal particles to give vertical and lateral support. I believe this to be one of the most fruitful lines of investigation and I am therefore sorry to see this line being treated as probably of little value lest it be thought that the idea underlying it is also of little value and so improved methods might not be sought for.

In the Punjab system of "Cheap Renewals" this filling of voids occurs automatically. I note that this paper advocates scoring at distances of 12 inches, but am doubtful if this is so sound in practice as the "Cheap Renewal" method.

Page 5 (k). I note very wide variations in local ideas about the rate of water-bound consolidation. From a very wide experience I confess I do not think first class consolidation can be done at more than 800 cubic feet a day for new consolidation, and if the metal is very hard, at not more than 600 cubic feet a day measured loose. In the "Cheap Renewal" method, the rate is greater by perhaps 50 per cent.

Madras, I note, does consolidation 4 to 7 times as fast. I cannot believe that such a rate as that is possible without the addition of unnecessary and dangerous quantities of earth, in other words, a sort of mud plum concrete. If that is actually the fact, I feel sure that true economy will be served by spending more on consolidation and by using less earth.

Any road consolidated with too much earth at once produces conditions which detract from the lasting properties of surface dressing.

2. Comments made by Mr. W. F. Walker, Executive Engineer (Meerut,) by post, on Paper No. K (I).

In my opinion it is neither possible nor necessary to lay down a specification which will be suitable for the whole of India where the materials used differ so widely from laterite to kanker and stone.

The various provinces already have their own specifications which have been drawn up to meet their local conditions.

In the United Provinces it is usual to make stone stacks 12 inches high whereas kanker stacks which settle appreciably after a time are made 13 inches high whilst both are measured as 12 inches high.

The example in the paper of a suitably graded stone gives the largest size as 1 inch. This I think is too small and the size for a finishing coat of stone should be at least $1\frac{1}{2}$ inches. Different sizes of metal are necessary if

the surface is to bind properly. In most cases the stone will be broken into different sizes under the roller.

Certain experiments have been tried in the United Provinces, with different blinding materials. Kanker bajri, stone bajri, moorum and sandy soil have been used.

It appears that if the road is to be surface-treated then sandy soil is perfectly satisfactory as blinding and no advantage is gained by using others which may cost up to Rs. 500/- a mile and which are merely brushed off the road at the time of painting.

If however the surface is to remain water-bound, then sandy soil is not satisfactory and some other material must be used. There is little to choose between the kanker bajri, stone bajri, and moorum but they must be measured up and paid for separately both to check the quantity used and because they may be expensive.

Experiments have also been made with hill clay. This is a clayey moorum which is spread $\frac{1}{2}$ inch thick on the old surface. The metal is spread over this and consolidated in the ordinary way. Special care has to be taken to water the road thoroughly in order to bring up the clay to the surface. It appears to be fairly successful but I myself prefer blinding with bajri.

3. Comments made by Rai Sahib Tulsidas Banerji, M.E.S., (Jubbulpore,) by post, on Paper No. K (I).

As for a long time to come water-bound macadam roads will continue to form bulk of Indian roads, any attempt to improve them economically by introducing a code of standard practice is very welcome. I therefore, congratulate Mr. Trevor-Jones for his splendid paper.

I do not however, quite follow the utility of stacking metal in continuous stacks with requisite gaps for drainage. It may be suitable for trunk roads, but is definitely otherwise for busy places and towns with numerous cross roads. The solution appears to be stacks of standard size spaced to allow sufficient metal for stipulated thickness of coat on the corresponding length of the road, where possible. This will enable easy counting and checking and also eliminate the tedious process of taping the entire length of stacks to arrive at the quantity actually supplied.

We are generally concerned with the wearing quality of the road. If it wears well, the result is economy in maintenance with better appreciation of the road surface. But the wearing quality depends on the constituent parts of the road, how they are assembled and finished. Metal is therefore the most important factor contributory to the life of a road. It should not only be sound, hard and tough, but when consolidated must be dense and capable of withstanding the destructive action of traffic. To achieve these, certain conditions are essential *viz.*—

- (a) the metal of graded stone of uniform sizes interlocked to each other,

- (b) consolidation without admixture of earth,
- (c) blinding with screenings of the same material as road metal.

It is equally important that correct use of templates for spreading metal should be rigidly enforced and the road surface frequently checked with a straight edge during the final stage of consolidation. Any defects noticed should be mended immediately. This will not only obviate the initial corrugations, but will also give a better riding surface.

There is however another school, which still believes in the importance of ungraded metal, but its result, as we all know, is early disintegration and dusty road, both uneconomical from financial and other points of view.

Author's suggestions in general, and specially that for introducing graded metal in road making are therefore very valuable and will enable provision of better roads for the same, if not, lower cost.

Para 15 of the Note is not clear as to the reason for a very wide divergence in the daily output of a steam roller. It would be interesting and perhaps helpful, if some more details in respect of thickness and nature of metal consolidated, type of roller used in Madras and Punjab were available. The maximum that could be had here (Jubbulpore) from a 15 ton roller is 800 cubic feet per day or 3 inches thick 16 feet wide, 3200 square feet. Metal is graded trap from 2 inches to $\frac{1}{2}$ inch.

4. Comments made by Mr. Murari Lal, Assistant Engineer (Punjab), by post on Paper No. K (I.)

The author in para 3 in the general note on the design of water-bound Macadam writes "The voids are filled with clay and stone dust which should be forced up from beneath during consolidation" but in para 14 says that "No earth or other material should be mixed with the metal before, during or after the consolidation." If no earth or clay is to be used, how the tiny interstices in the aggregate will be filled up with clay and stone dust to be forced from beneath. It therefore appears essential that a layer of $\frac{1}{2}$ inch of clayey earth or moorum should be spread over the soling coat or old metal before spreading the new wearing coat so that during consolidation the clay or moorum will be drawn up into the interstices by capillary action of water.

In the same para 3, the author has given an indication of a suitable grading of the aggregate to be used in consolidation but has not suggested how these various proportions have been arrived at to ensure the maximum density and how the individual voids in the mass aggregate have been determined. In order to ensure perfect inter-locking or compaction of the aggregate, it is very necessary indeed, that the individual voids between adjacent pieces of metal be just filled up with smaller pieces of metal; but as in a mixed aggregate containing all sorts of sizes no-body can predict with any precision as to how the different pieces of metal will arrange themselves under a roller so as to leave the minimum of voids, it seems that the only suitable method of grading the aggregate, particularly in the case of hand broken metal where personal factor comes so much into play, is that by a

trial and error method it should first be ascertained what quantities of different grades of metal mixed together and well shaken in a rotary drum will give the maximum weight for a given volume and then having found their percentages, the different grades should be collected and stacked separately for any given length of road in the manner described in paras 1 and 2 of the paper.

In spreading the aggregate biggest sized metal which should not be less than $1\frac{1}{2}$ inches gauge will be spread first, lightly rolled leaving spaces between the stone pieces; this will be followed by spreading of the medium gauge $\frac{1}{2}$ inch to 1 inch metal and finally the fine gauge $\frac{1}{4}$ inch to $\frac{1}{2}$ inch gauge inter locking into the bigger gauge preceding. This aspect of grading requires research and experimentation.

Para 4—Surface scoring should preferably be done diagonally and not at right angles to the direction of road traffic. This will help to avoid corrugations.

Para 9—In addition to a set of 3 spreading templates, there should be another set of three honing rods to align the top surface of metalling longitudinally to avoid bumps. Frequent use should be made of these rods. Further, instead of sets for different cross falls, it will be convenient to use only one template which will show on it various slopes by lines previously marked on it for different inclinations and with the aid of plumb-bob any cross fall can be laid out at site. This has been explained in paper No. 180 on specification on Highway curves in the Punjab Engineering Congress by me.

ANNEX.

SPECIFICATION FOR WATERBOUND MACADAM^a

ORIGINAL WORK AND RECONSOLIDATION.

SOUTH BIHAR AND CHOTA NAGPUR.

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1. Collection of Metal.—

Stone—The stone shall be taken from the quarry specified in the accepted tender and it shall be dense, hard, and tough; free from parallel fracture, crystal cleavage, weathering, earthy matter, moss, and such defects.

Quartzite of any colour, fine grained rocks like diabase, dolomite, phonolite etc., are all good. Vein quartz is to be regarded with suspicion as it frequently contains high development of crystal cleavage, either visible to the eye, or proved by throwing the specimen smartly on a hard surface.

Metamorphosed sedimentary rocks like black or other micaceous schists and coarse grained gneiss will not be accepted.

Breaking.—The size shall be according to the Indian Road Congress Standard, vide page 177, Proceedings, January 1936.

Two-inch metal.—This must wholly pass through a screen of square mesh of $2\frac{1}{2}$ inches side, and be wholly retained on a screen of square mesh of $1\frac{1}{2}$ inches side.

One and one-half inch metal.—This must wholly pass through a screen of square mesh of 2 inches side and be wholly retained on a screen of square mesh of 1 inch side.

The side is to be measured between wires and not centre to centre of wires, and the screen is to be held at an angle of 30° to the horizontal.

^a This Specification has been referred to by Mr. W. L. Murrell in his remarks on Paper K (I) [vide page 9 (k1)].

The size of wires composing the screen will be as follows :—

Screen size.			Size of wire.	
			S. W. G.	Approx. dia. inches
2½"	...	...	4	0.23
2"	...	...	5	0.21
1½"	...	...	6	0.19
1"	...	...	7	0.17

Unless otherwise specially stated in writing, the size of metal will be *two inches* for new metalling first and second course, and also for reconsolidating old metal with the addition of not less than three inches of new metal, the average picking-up of old metal being to not less than three inches depth.

Transportation of metal.—When metal is transported by motor vehicles or animal-drawn carts, care shall be taken that no metal is dropped on any portion of the road or roadside land.

In cases where the whole of the carting under the contract is done by means of animal-drawn vehicles equipped with pneumatic tyres, the contractor shall receive an additional payment of annas four per hundred cubic feet of stack measurement.

Where an alternative track exists, the contractor shall not transport metal over the metalled or sealed surface unless his vehicles are fitted with pneumatic tyres.

Stacking of metal.—Normally the metal be stacked fully into box frames with internal measurements 5'-0" × 5'-0" × 1'-1", the metal being struck off flush with the top of the frame. Such a stack will be measured as 25 cubic feet.

Without the previous permission in writing of the Subdivisional Officer or the Assistant Engineer, no metal shall be stacked anywhere on the crest of the road formation. All stacking will be upon clean, levelled, or evenly-sloped, firm ground on the roadside lands, and the stacks shall be as equidistant as possible along the road. All stacks will be free from over or undersized metal, chips, weathered or soft metal, flat shaped pieces, dirt, mud, vegetation or other undesirable matter.

Rate of payment.—The schedule rate includes quarrying the stone, breaking it to size, screening, transportation, stacking, payment of royalty to the authority who has the mineral rights, payment of compensation for transport through fields, etc., and all other incidental charges.

2 Arrangement for Traffic during Consolidation.—

Road closures shall be in accordance with the Bihar and Orissa Highways Act, 1926. On no account may any road be completely closed to traffic without the previous written consent of the Superintending Engineer, and unless the date and period of closure be advertised in the local press, and

unless notices be posted on all public buildings of local importance and on the section of road to be closed. These advertisements and notices shall give at least two weeks' clear warning.

Where the road is to be partially closed temporary roads are to be made for the traffic.

Motor vehicles should, where possible, be allowed to pass on the wider flank, whilst a separate track should be made for carts. The contractor must make and maintain these tracks at his own expense.

All obstructions and diversions must be clearly visible at a distance by night and by day, there being a preliminary warning by red lamp and red flag at a distance of 500 feet from the obstruction or diversion. At the obstruction or diversion there will be red reflex signs, red lamps or lamp boxes, and, in the case of diversions, there shall be an arrow to indicate clearly by day or by night the direction of take-off to the diversion.

All diversions other than on the road flank will be clearly marked by whitewashed stones or other such means.

3. Camber.—

By "camber" is meant the curve of the surface of the cross section of the metalled portion of straight or nearly straight section of road, and the "amount of camber" is the difference in level between the surface at the crown or centre of the metal, and the edges of the metal.

The amount of camber to be given in a road will depend on whether the surface is to remain as a water-bound one or it is to be surface-treated or sealed.

For surfaces that are to remain as water-bound and that are not to be surfaced or sealed, the amount of camber is to be taken as one-sixtieth of the full width of the metalled surface.

For surfaces that are to be surfaced or sealed after consolidation, the amount of camber is to be taken as one-hundred-and-twentieth of the width of the metal to be surfaced or sealed.

The camber of the section will be such that the middle third will approximate to the arc of a circle, while the outer thirds will be constant slopes tangential to the arc.

Templates for camber.—For work up to a width of 15 feet of metal there shall be light but rigid and strong full templates, with edge to the required camber, and each template will be complete either with a fixed spirit level or a plumb-bob arrangement. There shall be three such templates for each roller in action.

For work on greater widths half templates shall be used with fixed spirit level or plumb-bob arrangement.

4. Cross Fall, Superelevation, or Banking.—

By this is meant the difference in level between the outer and the inner edge of the metal on curved sections of the road, divided by the width of metal and multiplied by 100 to express the ratio as a percentage.

Curves with a radius of 1,000 feet and less are to be superelevated and widened in accordance with the following table:—

Radius.			Superelevation to be adopted. % of width.	Increase in width for a road width of 9 feet. Feet.
Feet,				
30	...	...	16.6	4.5
50	...	...	12.5	4.5
100	...	...	12.5	4.5
150	...	...	10.4	4.3
200	...	...	10.4	4.1
300	...	...	9.4	3.7
400	...	...	9.4	3.3
500	...	...	8.4	2.9
600	...	...	8.4	2.5
700	...	...	6.2	2.1
800	...	...	6.2	1.7
900	...	...	4.2	1.3
1,000	...	...	4.2	0.9

For metal widths on straight sections exceeding 9 feet, the widening on curves will be increased proportionately.

The above table refers to ordinary roads. For Trunk Roads, the instructions laid down in H. Criswell's "Highway Spirals, Banking and Vertical Curves" or similar works of reference will be followed, *vide* page 31 "Indian Roads" no. XI June 1937.

5. Lateral Support for Metal About to be Spread.—

(a) *Original Work*.—Where the road bed is boxed out, the earthen flanks or berms are sufficient lateral support for the newly spread metal.

Where the new metal is higher than the flanks, however, it must be supported by continuous borders of grass sods. These sods should be as large as possible so as to give a "bundh" at least 1 foot wide. They should be well consolidated by wooden or other rammers.

(b) *Reconsolidation Works*.—Sod or stone edging to be provided as described above, as the case may be.

Standard edging.—In cases where the picking-up of the old metal will result in an appreciable amount of salvaged material passing the $1\frac{1}{2}$ " screen, the following specification will be followed;—

Salvage edging.—That portion of the picked-up metal which passes the $1\frac{1}{2}$ " screen and is retained on the $\frac{3}{4}$ " screen, *vide* paragraph 6 "Screening" shall be used to form an edging on each side of the new metal.

Grass sods shall be placed along the edges of the metal to be consolidated as described in paragraph 5 (a) above, but on a line nine inches away from the edges of the old metal and on the outer side of it. Thus, where the old metal is nine feet wide, the two lines of sods shall be ten feet six inches clear apart.

The old metal shall then be picked up and screened on the flank of the road as described in paragraph 6 below, leaving a berm nine inches wide by average three inches depth on the inner side of each line of grass sods.

When the road bed is cleared of picked-up metal, these two berms shall be picked out so as to clear the road bed to the full width between the two lines of grass sods.

The earthy matter from these berms shall be thrown and rammed on the reverse side of the line of sod edging, the large pieces of old metal being thrown towards the centre of the road bed.

The salvaged metal or "Seconds" passing the $1\frac{1}{2}$ inch screen and also any small stuff received from picking out the nine-inch berms will then be laid in the road bed to a width of nine inches along each line of edging sods, and to such a height that its top will be flush with the top of the new metal when laid between these two lines of salvaged metal.

The new metal and the salvage edges shall then be consolidated simultaneously.

Note.—If there is insufficient salvaged material, rejected metal may be used in lieu of same.

(*Vide* Proceedings. Third Indian Roads Congress, page 12. Trevor-Jones on "Pusha" and page 166, Murrell on "Size Gradation".)

6. Picking up the Old Metalled Surface.—

Picking up.—The old metal shall be picked up to an average depth of three inches.

Picking up shall not be commenced nor finished on a line at right angles to the length of the road, but on a line 45° to it.

Where the metal is to be reconsolidated half width at a time, the first half will be picked up to half-width *plus* two feet.

Great care shall be exercised to see that the surface, after picking up, shall be—

- a True to cross section as specified in paragraphs 3 and 4.
- b True to longitudinal section.

Strict attention shall be paid to the elimination of bumps or humps which sometimes extend for many running feet of the old road surface. For this purpose the Overseer, the Contractor, and his mate shall each carry a length of 60 feet of fine fishing line on a small rectangular wooden frame, for constant checking of the longitudinal section, and the labour is to be prevented from excessive picking up of the old metal in the hollows.

The picking up of old metal will be done with hand pick-axes in such a way that the old metal will be broken as little as possible.

If dry, the old water-bound surface should be wetted. The picking up should be done, first in furrows about one foot apart "along" the road, and then transversely across the road.

Screening — Where it is evident that at least 20 per cent of the picked-up material will be refused by a $1\frac{1}{2}$ " square mesh screen, all picked-up material will be passed through a $1\frac{1}{2}$ " square mesh screen. What materials are refused by this screen are called "firsts" and they are to be kept for spreading back in the road bed.

The remaining picked-up material shall then be screened over a $\frac{3}{4}$ " square mesh screen.

The materials which are refused by this $\frac{3}{4}$ " screen shall be called "seconds".

The seconds are to be kept as salvage for filling into the trenches for the salvage edging.

The materials which pass the $\frac{3}{4}$ inch screen shall then be screened over a $\frac{1}{2}$ inch square mesh screen. What are refused are called "thirds", and what pass through are called "fourths".

The "thirds" are used partly for blinding the metal surface during wet rolling of surfaces which are to remain as water-bound macadam. If of good material, they may also be used as blinder with no. 2, Tar, after cleaning by washing and drying.

The fourths are used for final rolling or "polishing".

Notes.—(i) The $\frac{3}{4}$ inch and $\frac{1}{2}$ inch mesh screens shall be of square mesh the size being in the clear and not centre to centre of the wires.

ii The size of the wires shall be—

Screen size

Size of wire.

			S. W. G.	Approx. diam inches.
$\frac{3}{4}$ inch	...	...	8	0.16
$\frac{1}{2}$ inch	...	...	16	0.06

iii The screens shall be used at an angle of 30° from the horizontal.

(iv) No delay must be allowed in the use of the $\frac{3}{4}$ inch and $\frac{1}{4}$ inch screens, as rain may be expected with very little warning, and all the finer material will adhere to the coarse materials if they are allowed to become wet.

(v) There shall be two sets of each size of screen (i.e. six screens) per roller. The works staff shall not be allowed to use the screens as beds, or for any purpose other than screening.

(vi) The screens are to be the property of the contractors, and it is preferable to arrange for them departmentally, recovering the cost at a price to be stated in the notice calling for tenders.

(vii) No loose material is to be left on the road bed and all fine stuff not passed through the screens is to be swept up and thrown away before any metal is spread.

7. Spreading of Metal.—

(a) *Original Works.*—The metal shall be spread true to cross and longitudinal section, and evenly to the unconsolidated depth for each layer shown in the contract.

The metal spread shall be entirely free from all the defects mentioned under "Collection of metal" paragraph 1.

The first layer shall not be spread until the soling or other road bed has been duly approved by the Subdivisional Officer or the Assistant Engineer, or the person deputed by him.

The second layer of metal shall not be spread until the dry rolling of the first layer, including the rectification of defects, shall have been approved by the Subdivisional Officer or the Assistant Engineer or the person deputed by him.

Care is to be taken at the junction of old and new surface. The metal is to be spread so that, on consolidation, rapidly moving cars will pass over the junction without receiving a bump.

(b) *Reconsolidation.*—No metal shall be spread until the picking up has been completed and approved for a distance of at least 300 r. ft. of road.

The salvaged metal or "firsts" refused by the $1\frac{1}{2}$ inch screen shall then be spread uniformly over the picked-up surface.

While this is going on, the contractor shall mark with whitewash every 25th stack of new metal, beginning at the 13th stack from the commencement of the work. These whitewashed stacks shall be called the "rectification stacks".

All new metal *excluding the rectification stacks*, shall then be spread evenly over the road bed true to cross-section and to longitudinal section to a uniform depth of at least 3 inches.

Where the metal is to be reconsolidated half width at a time, the new metal is to be spread the full half width of the road *plus* fifteen inches.

The greatest care shall be taken by all concerned that one of the three templates referred to in paragraph 3 shall be used constantly in checking the camber.

There shall be a contractor's mate solely in charge of this work and he also will be provided with a length of 60 r.ft. of fishing line for checking.

All surface metal is to be hand-packed in conjunction with the template and line to ensure even spreading before dry rolling is commenced.

8. Dry Rolling.—

Both original and reconsolidation work.—If the roller is a powered one, care is to be taken that the gearing is in good order and that the driver opens and closes the throttle gradually. The prevention of initial bumps in rolling is of the utmost importance. The roller must not be stopped in the same place more than once. The furnace must not be raked out, nor the bunker replenished, over any of the uncompleted surface.

The dry rolling shall proceed first along one edge of the metal and its edging, and then along the other edge of the metal and its edging, in order to prevent degradation of the camber.

Where the metal is to be reconsolidated half width at a time the rolling shall be done over no more than the half width. The marginal fifteen inches of new metal shall not be rolled nor shall it be treated with "thirds" until the second half width is being consolidated.

Rolling shall be done in lengths not less than 300 feet, and the total length of road being picked-up, spread, and consolidated at any one time should not exceed 900 feet.

When the whole area has been dry-rolled 3 or 4 times it shall be inspected in order to ascertain by means of the template and 60 feet line, especially the latter, where the depressions exist in the work, and the extent and depth of such depressions.

All such places shall be thoroughly loosened by hand picking, and additional metal shall be spread from the whitewashed rectification stacks to make up the deficiency. These rectifications are to be done personally by a departmental employee especially skilled in the work, or under the direct supervision of the Overseer.

Any pieces of metal which crumble or disclose their weakness during the dry-rolling are to be carefully picked out and replaced carefully by hand with sound pieces of metal of about the same size from the rectification stacks.

When all defects have been dealt with, dry-rolling will proceed until the creeping or waving of metal before the advancing rollers has ceased.

Special Note.—The rectification of the hollows must be done shortly after the commencement of the dry-rolling and not later during the dry-rolling.

The departmental roller driver has a large responsibility in this respect. He also is to be provided with a 60 feet line, and he shall refuse to proceed further with the dry-rolling unless the depressions are rectified in the manner above specified shortly after dry-rolling commences.

In the case of original work, the spreading of the second layer of metal and its dry-rolling should now be proceeded with as described above.

Immediately on completion of the dry-rolling the remains of the rectification stacks, if any, will be carefully boxed as 25 cu. ft. stacks and shown in the metal balance.

9. Wet Rolling.—

On the completion of dry-rolling, the mechanical interlocking of the metal should be complete, but, to make sure of this, water should now be sprinkled liberally over the metal which should then be rolled, again starting from the edges, until there is no further creep or wave in the metal before the advancing roller.

*For surfaces that are to remain as waterbound surfaces
and will not be sealed or surfaced.—*

Coarse Blinding.—After the wet-rolling has been started and there is no longer any creep in front of the rollers, a very limited amount of "thirds" ($\frac{3}{4}$ "— $\frac{1}{4}$ ") screenings is to be scattered over the surface, and swept by soft grass brooms into the larger interstices.

It is important that not more than one cubic foot of these screenings should be used % square feet of road surface.

Where the metal has shown considerable tendency to crushing under the roller, the amount of screenings or thirds should be even less than one cubic foot % square feet.

Usually, much too much of these screenings is used, with the result that they work down into the already consolidated metal and interfere with the mechanical interlocking, later leading to corrugation.

All concerned are responsible to prevent this excess, and the roller driver should refuse to roll any surface treated to excess.

As soon as the coarse blinding has been placed by further rolling so that the surface prevents a uniform and fairly smooth texture, fine blinding shall be added.

Fine Blinding.—As the rolling proceeds, "fourth" screenings, passing the $\frac{1}{4}$ inch screen, shall be scattered lightly from time to time over the whole surface so as to form, with the continuous watering, a thin slurry in front of the roller wheels.

On no account should this fine material be allowed to cake or form a stiff muddy paste in patches over the surface. It must be continuously worked down into the metal as a thin slurry.

When 2 to 3 cubic feet of fourth screenings have been used % square feet of road surface in this way, the wet rolling will be considered to have been completed.

For surfaces that will be sealed or surfaced soon after consolidation.—A blinding need not be added, and the fine blinding should be added as above as soon as creeping ceases during wet rolling.

Where coarse blinding is not used during dry rolling, the amount of fine blinding may be increased to 3 or 4 cubic feet % square feet of road surface.

In this case also if the coarse blinding is of good material, it should be carefully conserved in 25 feet stacks, well off the road for use later as blinder in sealing work.

For original work.—Where no blinding material is obtainable from picking-up and screening an old surface, hard gravel or waste chips from the stone quarry should be used after screening through a $\frac{3}{4}$ " mesh and over a $\frac{1}{2}$ " mesh screen.

In such a case, in lieu of fine blinder or "fourths," stable earth should be sprinkled on the road.

Stable earth is that which is not too friable when dry and not too sticky when wet. Sand is bad because it is too friable and has no adhesive or blinding properties. Clay is bad because it may cause the metal to stick to the roller, thus necessitating re-doing the whole length.

Note.—(i) The contractor is specially responsible that no material which should be refused by a $\frac{3}{4}$ " mesh screen shall come on to the surface during wet-rolling, and the roller driver should refuse to roll until any such coarse stuff is removed.

(ii) Should the inspecting officer find that walking on the metal during wet-rolling results in a "scrunching" sound, it will be a sure sign that there is an excess of thirds in the body of the metal, and the whole lot should be picked-up, re-screened, and re-done from the beginning, including dry-rolling and wet-rolling. The same action is to be taken if it be found that the contractor is attempting to conceal depressions in the surface by spreading a layer of 'thirds' and 'fourths' in them.

10. Curing.—

On completion of the wet-rolling the surface shall be allowed to drain and dry out. This usually takes 2 or 3 days and, in the meantime, no traffic whatsoever is to be allowed over the section.

If necessary, the Bihar and Orissa Highways Act, 1926 is to be utilised to deal with offenders.

11. Building up the Flanks or Berms.—

Immediately after the section is opened to traffic, earthwork is to be done in the flanks.

In straight level sections of the road, this earthwork will be done in such a way that the side slope of the surface shall be 1 in 30.

Where the section is on a fairly steep gradient, the side-slope of the berm or flank is to be increased accordingly, being little if anything less than the road gradient.

On curves, the slope of the inner and outer flanks or berms shall be the same as that of the superelevated metal between them.

The inner berms shall be cut down to the required slope, and the earth obtained shall be utilised for building up the outer slope. On no account may borrow pits be made for building up the outer flank until the inner slope is completed.

The flanks or berms alongside the new metalled surface shall be well rammed for a width of at least three feet in order to prevent accidents owing to the left side wheels of passing cars sinking unduly into the new earthwork.

The flanks or berms shall be neatly fine-dressed so as to avoid bumps or hollows, and to a continuous slope to the edges of the formation, which edges will be continuous and parallel to the centre line of the metal.

The side slopes to the formation also will be continuous, even and fine-dressed. Should the contractor do excessive earthwork on the flanks or berms, the excess of earth shall be placed back in the borrow pits, at his expense, before the pits are measured for his bill.

Should there be any accident due to delay in building up the flanks and berms, or due to not ramming them to a width of 3 feet near the metal, the responsibility will lie with the contractor whose tender for the earthwork has been accepted, otherwise with the officer who failed to arrange the tender in time.

12. Alternative Method for Original Work.—

This method shall be used only on the written instruction of the Executive Engineer, given before the tender is accepted, and stating the exact locality where the method is to be used.

After dry-rolling of the first layer has been completed in accordance with paragraph 8 above, a uniform depth of 1 inch of mooram gravel shall be spread. Such gravel shall be free of large pieces which would be refused by a $\frac{3}{4}$ " screen, and must not contain more than 20 per cent clay. Over this unconsolidated gravel shall then be spread the second layer of metal as specified in paragraph 7 above, and the dry and wet rolling shall be done in accordance with paragraphs 8 and 9 above.

PAPERS Nos. L & P.

Mr. K. G. Mitchell (Chairman) :—I take it, it is agreed we take up Paper L, "Some aspects of Bituminous Road Construction in India" by Colonel G. E. Sopwith and Mr. W. A. Griffiths and Paper P, "Revitalisation of tarred or Bituminous surfaces" by Captain R. C. Graham together. I understand that Colonel Sopwith will introduce the first paper and reply to the discussion, while the second paper will, in the absence of the author, be introduced by Mr. Lawley.

The following two Papers were then taken as read :—

PAPER No. L.

SOME ASPECTS OF BITUMINOUS ROAD CONSTRUCTION IN INDIA.

By

COLONEL G. E. SOPWITH, M.C., and W. A. GRIFFITHS.

The object of this paper, contributed by representatives of manufacturers of Bitumen and Tar Products, is to present to the delegates to the Indian Roads Congress some aspects of road construction with a view to stimulating a discussion at the Meeting, and also to give the various delegates attending an opportunity of asking questions.

(It should be noted that the term "Bituminous" is used as a standard one and is applied indiscriminately when the authors refer to Bitumen or Tar).

The paper deals with the general principles only and does not set out specifications as it is considered that, with the continuous research and practical experiments which are continually being tried, frequent changes in the methods of treatment occur; therefore the present time is not suitable to lay down any hard and fast specifications for bituminous work. It is, we feel, generally known that the producers of Bitumen and Tar are always ready to help and advise engineers on their problems with recommendations based on the latest knowledge in their possession, and the authors feel that for the time it is better that this procedure should be carried on with rather than setting up a code of practice for bituminous work which might well be partially out of date before the code has passed its infancy. Again, climatic and physical conditions vary so greatly in India that it is impossible to give general details or specifications to cover all these conditions, whereas the manufacturers' technical advisers are continually inspecting and working in these varying conditions and are therefore in a position to give advice based on practical experience, and such advice is bound to be more accurate and helpful than any code of practice which may be produced.

In India the problem of treating roads is not purely an engineering one; the financial side plays a very large part. In the whole of India there are approximately only 60,000 miles of metalled roads (a large portion being untreated) and a sound road development scheme, bearing in mind that India is now, and will remain for a considerable time to come, mainly an agricultural country, must involve the improvement of these roads as well as the improvement of the existing unmetalled roads and the construction of feeder roads if the produce of the country is to be moved more easily and cheaply.

The finances of India are not limitless and to construct expensive types of road, except where local conditions make it essential, is definitely at present a financial impossibility. It is therefore in the interests of India that research into the cheaper methods of treatment, which will successfully stand up to the traffic it has to bear, should be undertaken with more concentration

than research into the details of the expensive types. It need scarcely be said that road engineers in India as well as the manufacturers of bituminous products are alive to this and are continually experimenting with cheap type construction with no little success. We have therefore the following suggestions to make :—

- (a) It is preferable to apply the cheapest treatment that will stand up to any reasonable estimated traffic. This can, if it is found essential, be supplemented by imposing a more expensive type of treatment later, should the increase in traffic exceed the estimate, without losing the value of the initial treatment, but the introduction of a more expensive construction should only be made when traffic conditions warrant it.
- (b) Never utilise the estimated savings in maintenance by treatment of any given length for any part of the financing of treatment of that length, but always use them as an aid to the improvement of other lengths.

Problems met in bituminous road construction :

The first road to be treated with bituminous material was laid nearly half a century ago, and at that time the sole object was the prevention of the dust nuisance. Today, this is still one of the main reasons for treating roads, but by far the most important is the protection of the surface from the action of traffic and climatic conditions which now prevail. The difficulty in finding a treatment, cheap in first cost and maintenance, to cure these problems is very great and is dealt with later on in this paper. If the traffic is considerable, the dust problem solves itself, because in these circumstances treatment has to take the form of providing a road with increased carrying capacity and a good riding surface. These conditions can only be obtained by the use of tar, bitumen or cement.

We now turn to the problems met where it is desired to decide on the type of construction suitable for the conditions of traffic using the road. There are three types of traffic utilising roads in India today which are as follows :—

- (1) Light traffic. It may be light rubber tyred motor vehicles or horse drawn vehicles.
- (2) Medium traffic, consisting of lorries and buses, with moderate bullock-cart traffic.
- (3) Heavy traffic, which consists of heavily laden bullock-carts and lorries.

For the purpose of this paper we consider that only two classes need be taken, that is, one with bullock-cart traffic and the other without. The destructive effect of the bullock-cart is so great that when considering treating a road, a method of treatment has to be evolved which will stand up to the bullock cart traffic it carries and if this is done, such treatment will suffice for any other traffic which uses the road.

Principles affecting the methods of dealing with the problems :—

Whether it is purely for the purpose of providing a dust cure or whether it is for providing a road suitable for heavy traffic, the first question to be considered is what is the existing road surface composed of.

Roads in India consist of either earth, laterite, kunkur, gravel, burnt brick or stone metal. Four or five years ago it was not considered practicable to treat laterite and kunkur with bituminous materials, and even burnt brick as a road building material was looked on with doubt. Today, however, as a result of experience gained in India and elsewhere, it has been found possible to evolve methods of treating these materials which have not only given a dustless surface and increased the life of the road composed of these materials, but also increased the traffic carrying capacity.

Early attempts at treating kunkur/laterite were not successful because at the time of putting forward recommendations for treatment of roads composed of these materials, the fundamental fact that unless a carpet is solidly bonded to the base it cannot last, was not taken into consideration. Practically any binder of an adhesive nature will bond to a clean surface, but under the action of traffic that surface will not remain clean very long; on its top a fine dust forms and the carpet begins to peel. This film of dust, caused by the action of traffic, is added to still further if the treatment which has been applied to the road is blinded with pieces of aggregate harder than the actual material of the road, as they tend to pierce down through the top surface. In other words, the cause of the trouble is the formation of a dust film which destroys the bond and causes the carpet to separate from the base. Therefore, in putting forward a recommendation for treating surfaces composed of these materials it is necessary to provide a treatment which will prevent the formation of dust on the surface of the base and, if this is not entirely possible, to provide a material which will absorb such dust as may be formed.

To obtain the above conditions a binding material which has powers of penetrating the crust of the base must be provided, and unless this can be done we are of the opinion that no cheap method can be satisfactorily applied, and, if funds are not available, it is better to wait until they are, otherwise the money spent will only be wasted.

To clarify the above we make the following statements :—

If the existing road is merely an earth road, it is no use attempting to convert such a road if it is realised that by so doing it will be called on to bear a traffic which necessitates a road with pucca foundations and a wearing coat which cannot be provided owing to lack of funds, and it is better to leave the road in its existing state until such time as funds have been collected to enable the engineer to make a sound job.

If a road has already been constructed before arriving at the decision on the type of treatment to be accorded to this road, one has to consider what type of foundation the material used in the construction will give and what type of traffic the road will have to carry. If laterite or kunkur have been used, they may make a satisfactory foundation provided they are protected from abrasion and are waterproofed and, provided the traffic is not heavy enough to cause crushing. These surfaces, treated first of all with a primer followed by a straight coat of tar or bitumen, will give fair results. If however the traffic is mainly composed of bullock carts we recommend that the surface of the existing roadway be lightly scarified and 3 inches of either stone metal or well burnt brick be spread, consolidated and then treated with bituminous material as for an ordinary water-bound macadam road.

An alternative to this is to lay a 1 inch or $1\frac{1}{2}$ inches premix carpet direct on to the prepared base of the laterite or kunkur, but by reason of the greater

thickness widening the area of the pressure distribution, the first method is preferable.

From this stage of construction we next come to the treatment of water-bound macadam roads. As the construction of stable waterbound macadam roads has been dealt with in Paper No. K (I), it is not proposed to touch on the methods to be employed to obtain the most satisfactory results, but it will be obvious to you all that to obtain satisfactory results and to obtain the maximum return for the money expended, the water-bound macadam must be first class. Even so, if the waterbound macadam road is left as such and is exposed to modern traffic conditions, it will rapidly deteriorate for the following reasons:—

- (1) Internal attrition caused by one particle of metal tending to move in relation to its neighbour, causing rounding of the edges, loosening of the interlock, thereby allowing ruts and potholes to form.
- (2) Vibration caused by fast moving vehicles which again tends to loosen the interlock.
- (3) Abrasion of the stone on the exposed surface.

To avoid these it is clear that the creation of a solidly bound upper crust which will effectively spread the pressure and prevent the movement of particles in relation to one another, is the only method of overcoming the causes of deterioration, and the best known method of doing this is by bituminous treatments of various types. By the use of bituminous materials, resiliency of the surface can be increased by cushioning; abrasion and crushing is accordingly decreased while the danger from internal attrition is lessened, finally all internal voids can be so completely filled that it will give a vortical and lateral support to the metal.

General Survey of Various Methods of Treatment :—If it is agreed that a bituminous material will fulfil all the claims made for it in the preceding paragraph—and we feel that this is so—the next points to be considered are the methods to be adopted to meet the varying conditions and the varying qualities of material available in India for road construction. There are five types of construction which are now advocated in India.

- (1) Surface treatment blinded with sand, dry chips or gravel.
- (2) Premixed chips or gravel, either singly or with sand.
- (3) Thin carpets of premixed stone with or without sand.
- (4) Grouts.
- (5) Thick carpets of premixed stone with or without sand.

The question which faces the engineer is "What type of construction shall I use in surfacing my road?" As we have already mentioned, this will depend on traffic conditions largely, but also on the type of material available locally or within a reasonable transportable distance. With regard to traffic conditions there are two alternatives. Either the road shall be built to meet the present requirements, or else one can look ahead and endeavour to estimate the future developments of traffic. If the latter course is adopted then the engineer will be called upon to build what may now be an unnecessarily strong and expensive type of construction for present conditions but should give him

5 (1)

a trouble-free road for 10 or 15 years, but, as it is impossible to gauge or predict the development of traffic, to do this would be a waste of public funds and it is therefore, in our opinion, better to treat the road according to present-day traffic conditions, which surface would, as we have stated earlier on, if traffic should increase sufficiently to warrant a more expensive type of surface being laid at a later date, form a suitable base and therefore it would not be entirely lost.

It will therefore be seen that it is not possible to lay down any rules at present by which engineers can be guided, and we would again remind you that the manufacturers of bituminous materials are only too willing to send one of their experts to discuss your problems with you and to advise you in the light of their experience of conditions in other parts of India as to the best, cheapest and most suitable type of bituminous construction which you should adopt for your roads.

(1) Surface dressing, as its name implies is a dressing of the surface with a binder. The function of the binder is to provide a waterproof protective coat over the surface of the road, to bind the crust and also to bind to the surface and to each other all particles of fine aggregate between the stones on the road so that they cannot be removed by traffic. Actually surface dressing does a little more than this, because the method of application is to pour the bituminous material over the surface of the road and then blind it with stone chippings and/or sand. This blindage is absorbed by the bituminous material and in time quite an appreciable thickness of carpet is built up. This consists mostly of stone and/or sand and acts as a cushion between the traffic and the stones in the road, thereby absorbing much of the impact shock and, further more, prevents abrasion and weathering of the stone of which the road is composed and, consequently, materially lengthens the life of the road.

Where the traffic warrants it, a stronger type of surface dressing may be obtained by the application of the bituminous material in two coats. By this method a thicker carpet is obtained and is naturally stronger than the single coat, but this procedure is only recommended where the water-bound macadam is really first class and traffic conditions are not likely to alter very considerably.

Surface dressing, if laid on a good strong macadam road, will carry almost an unlimited amount of motor traffic and an appreciable quantity of iron tyred bullock-cart traffic. If, however, the amount of iron tyred bullock-cart traffic is greater than surface dressing will stand upto, a more elaborate type of bituminous construction is necessary.

(2) & (3) This brings us to Item 2, which is premixed chippings or gravel either singly or with sand. Usually this type of carpet is laid to a thickness of 1 inch and can therefore also be termed a surfacing method. By this we mean that the 1-inch carpet is laid on to the surface of the road to protect it and not, like the heavier types of construction which are dealt with further on, an incorporation of the bituminous material in the road itself. In surface dressing the bituminous material is applied to the road and then blinded with chips. With 1-inch carpets the chips and stone are coated with the bituminous material before they are spread on the road. A great advantage of this is that the amount of bituminous material used can be regulated, and it can be predetermined exactly how much material the chips or gravel and sand available in the locality where the work is to be carried out, will carry. This

means not only a saving in bituminous material and therefore a saving in the cost of the work, but also provides a more scientific method and control.

(4) We have now dealt with surface dressing and thin carpets. By both these methods, it has been explained, only the crust is protected and the protection which is afforded by these methods is limited by the amount of traffic they have to carry. If it is considered that the traffic is too intense for those types of construction then the engineer must consider a more expensive and more lasting method, which brings us to the grout.

Grouting resembles water-bound macadam, except that a bituminous binder is used in order to hold the stones in position. In water-bound macadam, broken stone is spread on the road and consolidated; grit is then washed into the voids with water in order to pack the stones with the grit, which will prevent them from being displaced under the action of traffic. Grouting is exactly similar, except that the water is displaced by the bituminous binder. The binder percolates down through the voids, coating the stones as it passes, until the bottommost stones are reached. Stone chips are then blinded over the surface with the object of filling the open voids between the stones, until the carpet is as dense as possible. The whole road is then rolled as in water-bound, after which it is given a seal with a bituminous material.

This type of construction will carry any amount of motor traffic and a large quantity of iron-tired bullock-cart traffic, as the effect of the bituminous binder between the stones, is to cushion the stone so that it is able to resist impact shocks and eliminate internal attrition.

The methods so far dealt with can be adopted with whatever type of bituminous material the engineer wishes to use, that is to say, they can be equally well done with hot applied materials as with cold applied materials.

(5) We have now dealt with light, moderate and medium heavy traffic, which leaves us with the last item of heavy traffic. As has been stated, for heavy concentrated loads and severe impact shocks it is necessary to introduce the binder into the road or to coat the stones with the binder. We have already explained the method of introducing the binder into the road and we now set out to explain the method of pre-coating the stone with the binder, and also to show the advantages of this method.

The process consists of mixing graded stone with a bituminous binder. This can be done either by hand—a long and rather tedious process—by mixing in revolving drums, or by mechanical mixers. Either of the last two methods mentioned will give satisfactory results. After the stone has been coated it is spread to the required thickness and rolled. Chips are then pre-coated with a bituminous binder and spread over the surface of the stone so that they will penetrate into the voids. The whole surface is then rolled in order to force the chips down into the interstices.

The advantages of pre-coating the stone and chips in this manner over the grouting method are briefly as followings:—

(a) Premixing ensures that every particle is properly coated. In grouting this is not possible as the bituminous material can only coat such surfaces of the stone as it comes in contact with.

(b) With premixing, the coating on the stone is thin and there is no excess of binder; in grouting the binder has to find its way as best as it can into the interstices between the stones and consequently an appreciable quantity collects at the bottom. Such excess is not only a waste but also detrimental to the road, as an excess of binder acts as a lubricant rather than as a binder.

(c) premixing allows a denser carpet with a smaller percentage of voids. In the grouting method, in order to allow the binder to flow down and reach the stone, it is necessary to have fairly large interstices, between the stones, and the voids between the stones must not be filled with smaller fragments otherwise the flow is stopped. Further, by premixing a graded stone can be used, that is to say, a stone composed of varying sizes of fragments, the smaller of which will fill the voids between the larger and so give a more stable carpet.

Provided the stone metal is really hard and tough, this type of construction is more scientific than grouting and it will carry the normal iron tyred traffic found on roads outside the larger cities in India. It is generally laid to a consolidated depth of $2\frac{1}{2}$ inches. The cost of carrying out this type of construction is no more than that of grouting on account of the saving effected in the quantity of bituminous material required.

We now come to the last stage. In premix macadam the aggregate consists of graded stone and chips are used in an endeavour to fill the voids between the stone. While, for reasons we have stated, premix macadam gives a much denser carpet than the grouting method, there is still an appreciable quantity of void left between the stones which are not filled. We feel that it will be obvious to you all that the strongest type of construction which could be laid would be one where all the voids are filled and the spaces between the stones packed tight with a material which prevents the stones from moving. Bituminous concrete is this type of construction and answers the requirements given above. By taking one size of stone and pre-coating it with a bituminous binder, to which is added pre-coated sand, a strong dense carpet is obtained. In view of the fact that no small stones are used, there is no danger that they might not go into their proper place between the big stones and thereby prevent proper interlocking. The sand is used in their place to fill the voids between the stones, thus obviating this possibility. The coated sand makes an excellent material for filling the voids as, at the time of laying, it is sufficiently plastic to mould itself to the shape of the voids and so it fills every nook and cranny in them. After consolidation the pre-coated sand sets hard thereby rendering it impossible for the stone to move even under the heaviest traffic.

We have expressed our opinion that a carpet composed of stone and sand is the most scientific form of construction, because the voids are completely filled and the maximum density obtained.

The question now arises whether it is not equally important to follow this principle when blinding surface treatment. In surface treatment blinding is usually carried out with dry or premixed chips or gravel. The fact that crushing or abrasion may convert a portion of this into dust suggests that it may be sound to anticipate this by replacing the small size of chips by sand, as the presence of the fine material will provide a cushioning effect and decrease the risk of excessive crushing. Some engineers contend that for blinding a primer only sand should be used, whereas others believe that stone

or gravel with sand is preferable. For a subsequent coat it is generally agreed that stone or gravel should be recommended. Sand, however, has the property of absorbing a large quantity of binder per cubic foot. This suggests that the cost of binder may be increased owing to a larger quantity having to be used. On the other hand the substitution of small chips by sand may effect a saving. The financial aspect, therefore, is one that can only be worked out locally.

A fair amount of experiment and research on these lines has been made, particularly in Bihar, but sufficient time has not elapsed to produce results, from which it can be said definitely that the idea is a sound one, and we are of the strong opinion that much more extensive experiments in all parts of India are necessary before judgment can be passed. As cushioning is an important part of the idea, it follows that the main principle is to fill the lower voids between the chips without interference with their interlocking. If sand is first spread over the binder in surface treatment and then the chips, the sand may absorb too much binder to allow the chips being firmly held to the surface and to each other unless a greater quantity of binder is used. If on the other hand, to avoid using more binder, the chips are first spread and then the sand, possibly a day or two later, there is no guarantee that the lower voids will be densely packed. This appears to be of greater importance when dealing with re-treatment of an already treated surface, which is hard and does not have the resilience a primer blinded with sand, or sand and chips possesses when a second coat is imposed after a short interval.

Possibly the best method of all would be to premix the chips and sand as though a bituminous concrete was being prepared, but this involves the trouble of mixing and possibly greater expense. As we have already stated we strongly believe that extensive experiments on these lines would be advantageous.

The readers of the paper will by now have realised that the authors regard the whole question of road improvement and construction in India as being in too fluid a state and too conditional on local circumstances of material and climate to enable hard and fast specifications to be laid down. There is, however, one matter on which standardisation has been reached and that is the size of stone metal for premix carpets and of chips for surface dressing, and we therefore give this information here, drawing attention to the fact that the principle is to attain the maximum density possible in a carpet (except for very large cities the necessary apparatus for exact grading is a practical impossibility and therefore grading as recommended is the best that experience shows can be obtained by hand-breaking) and proper interlocking of chips for surface treatment. The size and quantities given are normal but are subject to variations in special circumstances.

**GRADING AND QUANTITY OF DRY CHIPS OR GRAVEL
FOR SURFACE TREATMENT.**

(a) *If tar is used:—*

For first coat 3 to 3.5 cubic feet per 100 square feet.

Grading : $\frac{3}{4}$ inch to $\frac{1}{2}$ inch ... 60 per cent.

$\frac{3}{8}$ inch to $\frac{1}{4}$ inch ... 40 per cent.

For subsequent coats : the quantity of chips used is dependent on the amount of binder used ; approximately, the quantity required is $1\frac{1}{4}$ to $1\frac{1}{2}$ cubic feet per 10 pounds of binder. If the quantity to be used is 3 cubic feet or less, then the maximum size of the chips should be $\frac{1}{2}$ inch ; if 5 to 6 cubic feet, then the maximum size should be $\frac{3}{4}$ inch.

Grading : 60 per cent large size.
40 per cent small size.

(b) *If bitumen is used :—*

For first coat 4 to 5 cubic feet per 100 square feet if the surface being treated is rough ;

3 to 4 cubic feet per 100 square feet if the surface being treated is smooth.

The grading should be :—

For rough surface $\frac{3}{4}$ inch to $\frac{1}{2}$ inch ... 100 per cent.

For smooth surface $\frac{3}{8}$ inch to $\frac{1}{4}$ inch ... 100 per cent,

GRADING OF STONE FOR PREMIX CARPETS.

(a) *If tar is used :—*

For the main carpet $\frac{2}{3}$ rds large sized stone and $\frac{1}{3}$ rd small sized stone should be used.

For topping or wearing courses : 60 per cent of large and 40 per cent of small stone should be used.

Thickness of carpet	GRADING.	
	Large gauge $\frac{2}{3}$ rds of total.	Small gauge $\frac{1}{3}$ rd of total.
$\frac{3}{4}$ inch ...	$\frac{1}{2}$ inch	$\frac{3}{8}$ to $\frac{1}{4}$ inch.
1 inch ...	$\frac{3}{4}$ inch	$\frac{1}{2}$ " $\frac{3}{8}$ inch.
$1\frac{1}{2}$ inches ...	$1\frac{1}{4}$ to 1 inch	$\frac{3}{4}$ " $\frac{1}{2}$ inch.
2 inches ...	$1\frac{3}{4}$ to $1\frac{1}{2}$ inches	$\frac{3}{4}$ " $\frac{1}{2}$ inch.
$2\frac{1}{2}$ inches ...	$2\frac{1}{4}$ to $1\frac{1}{2}$ inches	1 " $\frac{1}{2}$ inch.

For topping course :—

Carpets of $1\frac{1}{2}$ inches and over (a topping course is not usually applied on carpets thinner than $1\frac{1}{2}$ inches).

Quantity of material required :

4 cubic feet per 100 square feet.

Size for $1\frac{1}{2}$ inches carpets :—

$\frac{1}{2}$ inch ... 60 per cent.

$\frac{3}{8}$ inch to $\frac{1}{2}$ inch ... 40 per cent.

for 2 inches and over :

$\frac{3}{4}$ inch to $\frac{1}{2}$ inch ... 60 per cent.

$\frac{5}{8}$ inch to $\frac{3}{4}$ inch ... 40 per cent.

If no wearing course is to be superimposed the quantity of chips should be increased from 4 cubic feet per 100 square feet to 6 to 8 cubic feet per 100 square feet the largest sized stone remaining $\frac{3}{4}$ inch.

Wearing course :—

If the wearing course is applied dry the usual quantity is 3 cubic feet per 100 square feet. If, however, it is premixed the quantity should be increased to 4 cubic feet and the grading will be as follows :—

For $\frac{3}{4}$ inch carpet : $\frac{3}{8}$ inch ... 60 per cent.

$\frac{1}{2}$ inch to $\frac{3}{8}$ inch ... 40 per cent.

For 1 inch & over : $\frac{1}{2}$ inch ... 60 per cent.

$\frac{3}{8}$ inch to $\frac{1}{2}$ inch ... 40 per cent.

(b) *If Bitumen is used :—*

Usually a premixed macadam carpet is not laid to a greater depth than $2\frac{1}{2}$ inches consolidated and the biggest sized stone should not exceed $1\frac{1}{2}$ inches. If, however, a consolidated depth of 3 inches or more is to be laid, then the size of the stone may go up to $2\frac{1}{2}$ inches.

The grading of stone for normal $2\frac{1}{2}$ inches premixed macadam should be as follows :—

50 per cent of $1\frac{1}{2}$ inches to $1\frac{3}{4}$ inches stone.

25 per cent of 1 inch to $1\frac{1}{4}$ inches ..

25 per cent of $\frac{1}{2}$ inch to $\frac{3}{4}$ inch ..

Mixed seal coat :—

If a mixed seal coat is used it should consist of $\frac{5}{8}$ inch to $\frac{1}{4}$ inch stone chips or grit, 8 cubic feet of chips being required per 100 square feet.

If a liquid seal coat is used then the chips should be applied dry at the rate of 6 cubic feet per 100 square feet the size of the chips being $\frac{1}{2}$ inch gauge.

11 (1)

In conclusion the authors hope that this paper will prove of interest to members of Indian Roads Congress and will stimulate thought and discussions on methods of bituminous road construction. We reiterate that the main points we have tried to bring out are :—

- (a) Not to waste funds on expensive types of road construction when a cheaper treatment would be sufficient for existing conditions of traffic.
 - (b) To evolve by experiments and research the best ways of effecting the cushioning that is so desirable to defeat the crushing of stone chips under heavy traffic, especially under iron tyred bullock-cart traffic.
 - (c) To utilise to the utmost the experience and research work of the various manufacturers of bituminous products by keeping in touch with the technical staff of their organisations.
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DISCUSSIONS ON PAPER No. L.

Colonel G. E. Sopwith (Author):—A perusal of the paper will have prepared you for the fact that the Authors are not convinced that the present is the time for the production of a comprehensive Code of Bituminous practice. Our view is that, while undoubtedly such items as the preparation of the road prior to treatment with Bitumen or Tar can be dealt with and also such as size of metal and chips, the methods of construction and of application are in a constant state of flux. This is not of great importance to those engineers who now habitually use bituminous binders and are in touch with the manufacturers, but we feel that, in areas and places where road improvement has not started or is in its early stages, the provision of specifications direct by the manufacturers backed with personal experience at the site of work, is, in our opinion, a sounder method than the possible wrongful interpretation of hard and fast rules laid down by the Indian Roads Congress.

That is our view but the decision on this must rest naturally with the members of the Congress and it is for them to decide whether a Code should be written now and, if so, how far the Code should go in detail.

If the Congress decide in favour of a Code, whether covering the whole ground or only part of it at the present time, we are strongly of opinion that it should consist of a combined section in which details of such matters as preparation of surface, which are common whatever product may be used, should be set down and then of separate sections dealing with the specifications for Bitumen and Tar respectively, as, owing to certain fundamental differences in characteristics, it is impossible to produce specifications which can without alteration be used, no matter which binder is chosen.

We need scarcely add that, should the decision of the Congress be in favour of a Code now, the manufacturers will give all help in their power by preparing specifications and so on, to aid whatever body may be set up to draft the Code.

We would like to add that we wrote the paper purposely in very general terms because we thought that thereby we should get possibly more constructive criticism. We have received advance copies of remarks by two members which suggests that we were correct in our supposition. Doubtless, we shall hear further criticisms during the discussion and will deal with all of them at the conclusion.

Mr. W. L. Murrell (Bihar):—I confess that I had been anticipating a paper which would be a first step to enable the Indian Roads Congress to arrive at standard specifications for different methods of construction and maintenance in different zones in India.

And I am disappointed.

In the first place, I cannot agree that the present is not a suitable time to lay down hard and fast specifications for bituminous work. Indeed these specifications are already long overdue.

The United States of America and most of the British Dominions have for years had definite codes, though the climatic and physical conditions in these countries are no less diversified than in India.

If we feel that the specifications we use to-day are likely to be superseded tomorrow, we can do as the Country Roads Board, Victoria, have done.

By undoing a cord which binds their "Book of Instructions on the Bituminous Surface Treatment of Roads, 1936", it is possible to quickly take out old loose leaves, and add up-to-date leaves.

While referring to this book, I would suggest that we might well follow its Divisions 2, 3, 5 and 6. A copy has been made available in the Congress Library.

My next point is that, though I know that the producers of bitumen and tar are always ready to help and advise engineers on their problems, I do not think that we, road engineers, can now remain content with an arrangement which ties us to the apron strings of the tar and bitumen producers.

In the absence of standard specifications for even the simplest work we must apparently go running to the producers for advice.

Personally I think the arrangement is intolerable.

I would go further and say that, if we are to have teachers who must advise us on each and everything we do, we are entitled to expect that our teachers should keep us up-to-date.

In this respect I am anxious because our teachers, the authors of the paper, appear to have failed us in the following points:—

(1) The paper refers to the Bihar process of using a primer coat of thin binder and sand in conjunction, with a second coat of thicker binder and chips, as being experimental.

It is nothing of the sort.

Two-coat work has been the standard practice in certain States of Australia for a number of years.

So far as Chota Nagpur is concerned, it is now well over two years since I discarded the specification of the tar and bitumen producers in India, and adopted the overseas method, suitably modified to suit Indian conditions.

Permit me to enlarge a little on what has been referred to as the Bihar process.

According to the instructions received from the tar and bitumen interests, we used to spend a lot of time in 1935 and 1936 in Chota Nagpur thoroughly cleaning the water-bound surface and opening the interstices between the pieces of metal so that the edges of the metal were proud to the extent of 1/16 to 3/16 of an inch.

14 (1)

Besides the extra cost of this thorough cleaning, the old method had two great disadvantages.

In some cases the metal became loose and there was difficulty, not only in brushing the dust out of the interstices, but also later while spreading the binder. It was difficult not to dislodge the pieces of metal also.

The other great disadvantage was that the consumption of binders, Road Tar No. 2, Spramex, or Socony 105, was very high.

The tar went down at about 50 pounds and the straight bitumens at about 60 pounds per hundred square feet.

This consumption was higher than advocated by the tar and bitumen interests but we could not do much better in practice.

Having seen the priming coat system in use in Australia, two years before that, I decided to pay less attention to cleaning, and to attain the necessary keying to the water-bound surface by using a more penetrating primary binder or primer.

As No. 1 Road Tar was a good deal cheaper than the bitumen compounds, we tried it, and found that it went on at 35 to 37 pounds in cool weather, and 30 to 32 pounds in warm weather.

But this did not soak in rapidly enough, and it had to be blinded or blotted with sand at about $2\frac{1}{2}$ cubic feet per hundred square feet.

After about 2 months we did the second coat, or body coat, with 28 to 30 pounds of Road Tar No. 2 or 30 to 35 pounds of straight bitumen, depending on whether the weather was hot or cool. It was generally hot. This body coat of binder was blinded with $\frac{1}{2}$ inch chips (Indian Roads Congress Standard), $3\frac{1}{2}$ to $4\frac{1}{2}$ cubic feet for the tar, and $\frac{3}{4}$ inch size $4\frac{1}{2}$ to 5 cubic feet for the bitumen.

This has been the standard practice for nearly three seasons, except for some increase in the quantity of chips.

We claim

(i) Less trouble with the water-bound surface, and more speed in getting the work done efficiently, with less supervision.

(ii) Somewhat less expense, as the amount of binder used is much the same, and the No. 1 Road Tar is cheaper than the straight bitumen it displaces.

(iii) The primer penetrates to a certain extent the blinding material between the pieces of metal, thus acting as a shallow semigrout and strengthening the road crust.

(iv) The primer makes the overlying blinder and chips of the body course stick more strongly to the pieces of metal in the road surface. This

is especially important where the stone metal has a greater affinity for water than it has for the binder used with the chips.

(v) The No. 1 Road Tar and sand form a film rich in binder and so, capable of absorbing some finer material, thus delaying or preventing the formation of the dust film.

(vi) The No. 1 Road Tar and sand form a cushion between the stone chips above and the road metal below. The chips, under very high compression between the steel tyre and the pieces of road metal, are less likely to be crushed when so bedded or cushioned.

This is really a modification of the American and Australian universal practice of priming. They use much less viscous primers, and they use them cold. The primer is allowed to stay on the road till it is pretty well all soaked into the water-bound macadam so as to allow traffic in 24 hours even without any sand being used to blind or blot it. These countries, however, have not got the steel bullock-cart tyre problem, and so, the No. 1 Road Tar, really used by Chota Nagpur in the first place as a make-shift primer, is probably better for India than the thinner unblinded primer used in America and Australia.

We are now trying cold bituminous binders and sand but it will be a year or two before we can start forming conclusions.

(2) The paper does not mention the process known as "drag-brooming" and which is described by Captain Graham in his paper introduced to this Congress today.

In Chota Nagpur we have done a little drag-brooming and we have a larger programme in the current season.

It is my firm conviction that, just as the Chota Nagpur two-coat work is a great advance on the heavy single coat work advocated by the authors of the paper, drag-brooming is a great advance on the two-coat work I introduced into Chota Nagpur, 2 or 3 years ago.

(3) The paper fails also to mention the most efficient of all methods of surface-treating a road. I refer to the method of spreading a pre-mix by means of a sort of drag-planer, a process called "Drag-Spreading." Originating in Australia some 6 years ago, this method is now superseding other methods, even in America.

It is true that drag-spreading makes somewhat higher demands on plant control, but the method is very economical in binder material, which is the chief item of expenditure in our work. Apart from this, the drag-spreading method gives the perfect riding surface, and our teachers might at least have mentioned it in the general survey.

As regards the grading and quantity of dry chips for painting purposes, I think the authors have given some very useful figures; but I would like to make a few suggestions.

(a) Instead of mixing the large size and small size chips and then spreading the mixture over the binder on the road surface, it is better to spread the large size first, roll once to fix the large size chips, and then spread the small size.

This method results in less chips being thrown off the road by subsequent traffic, and hence a thicker seal coat results.

(b) Some mention might have been made of the economy that can be achieved wherever chips are very expensive and sand is cheap, by using a less amount of chips and making up the deficiency with sand. In this case the chips are spread evenly and fixed by rolling once or twice before spreading the sand, and then fully rolling.

It is to be hoped that the tar and bitumen producers in India will soon reconsider their decision not to draft a series of zone specifications. If they have sufficient zone knowledge to enable them to advise, then they must have sufficient knowledge to enable them to prepare broadzone specifications.

If necessary, we, road engineers, will ourselves take on the job of preparing the specifications, though our daily routine duty and numerous special and urgent jobs allow us very little time for such work. But a nicer and more helpful company than the representatives of the Tar and Bitumen interests, would be very hard to find, and it is inconceivable that they will continue to withhold the specifications.

Mr. N. Das Gupta (Calcutta) :—As an engineer of one of the principal asphalt manufacturing firms, I feel that I am competent to say one or two words about the excellent paper presented by my friends, Colonel Sopwith and Mr. Griffiths.

For treatment of kankar, laterite and broken bricks, they recommend two treatments, namely :

- (1) Two coat treatment using a primer for the first coat.
- (2) Providing 3 inches stone metal and then two coat painting for roads-carrying some bullock cart traffic.

I agree with them, but I would like to suggest an alternative treatment which I specified for a road in North Bihar and found it to be very satisfactory for localities where stone is very expensive and for roads carrying fairly heavy bullock cart traffic.

This treatment, which is known as $2\frac{1}{2}$ inch sheet macadam consisted in laying:

- (1) 1 inch to 2 inches jhama or overburnt brick metal, pre-mixed with a cutback asphalt at about 20 cubic feet per 100 square feet. About 1/3rd gallon of cutback was used per cubic foot of jhama metal.

- (2) Pre-mixed sand seal at 4 cubic feet per 100 square feet. About 3/4 gallon of cutback was used per cubic foot of sand.

The cost of this treatment at this place was Rs. 16/5/- per hundred square feet, which compares favourably with the cost of providing 3 inches metal and subsequent two-coat painting.

As regards the reasons for the failure of water-bound roads, on page 4 (1) the authors have not taken into consideration two more reasons, which are :

Actual crushing of the metal.

Destructive action of rainfall.

In paragraph 2 on page 4 (1) while enumerating the advantages of application of bituminous products, the authors have, unfortunately, overlooked the most important property i.e. the water-proofing property of bitumen.

As regards the classification of the types of construction, I think that treatments 2, 3 and 5 are virtually the same and we may term these types of work as pre-mixed macadam or plant-mix macadam. I would like to suggest the following classification, which you will find is more scientific :

- (1) Surface treatment.
- (2) Pre-mixed macadam.
- (3) Penetration macadam or Grouting.
- (4) Bituminous concrete.
- (5) Road-mix or mix-in-place construction.

As regards the choice of specification, the authors have considered two conditions, namely, traffic and availability of road metal, but they have unfortunately neglected the most important condition, that is, funds at disposal.

Referring to line 13 of page 5 (1), you will find that they have used the words—best, cheapest and most suitable. Well, the terms "best" and "cheapest" are always contradictory. I think the words "most economical" would have been most suitable.

Now, regarding the choice between pre-mixed macadam and grout, the authors have shown preference for the former type of construction. I agree with them that in this type we require less bituminous material and the aggregate can be uniformly covered, but, I believe, the choice really depends upon the intensity of traffic and the quality of the aggregate as regards bitumen-water Affinity. It has often been found that the thin film of bitumen round some particular class of aggregate peels off by the action of rainwater. With this type of aggregate and with roads carrying intensely heavy bullock-cart traffic grouting should be recommended.

As regards scientific control, I believe it applies equally to pre-mix carpeting and grouting. By taking a weighed quantity of bitumen and spreading it over a measured area, we can easily control the rate of application. Further, grouting has several advantages over the pre-mix type of work as regards operation, which are as follows :—

- (1) No overhead charges for hire and transport of mixing plants.
- (2) Easier to lay; average skilled cooly can produce excellent results.
- (3) Greater factor of safety by having a relatively large quantity of bitumen.

The superiority of grouting work lies in :—

- (1) Relatively thicker film in between the metal and the chips, which makes the pavement more resilient and durable.
- (2) No stripping of bitumen by the action of water in case of silicious stones, such as granite, quartz, quartzite etc.
- (3) Greater carrying capacity, specially for the iron-tired bullock-carts.

Mentioning about the defects of grouting methods, the authors have mentioned that the excess binder acts as a lubricant. I do not know much about tar, but I can say that 30 to 40 percent penetration asphalt, when used at the correct rate, cannot act as a lubricant at ordinary temperatures. Besides, the metal and the chips are interlocked together. I am inclined to think that, up to a certain limit, the thicker the film, the greater will be the adhesive strength for bitumen and, therefore, the greater the stability of the pavement. A stone, coated with a thin film of binder, can easily be dislodged, but with a relatively thicker film, it is quite difficult to do the same. So, excess bitumen is an advantage.

Their second point is that the quantity of bitumen that may be at the bottom during the process of grouting is a waste. I again differ with the authors. In Bengal, the seal coat is given after 3—12 months and during this interval the bitumen from the bottom gradually works up by the action of traffic and heat.

Referring to paragraph 4 of page 7 (1), we find that the authors prefer one size of stone rather than graded stone for making bituminous concrete, as they consider that the smaller size chips would interfere with inter-locking. I agree with them so far. But, the point which disturbs me is, whether the sand-bitumen mastic, in between the voids of one size stone, would be as strong as graded smaller chips and sand. I think the main principle in bituminous concrete lies in the elimination of all voids by using graded chips, sand and filler in such percentages which very nearly correspond to the Maximum Density curve. With open graded pre-mix, however, we can eliminate filler, and even sand, but we must have graded chips to fill up the voids of the immediate larger chips. Moreover, in bituminous concrete type

of work, the stability is obtained by filling up of all voids and not by mechanical interlocking. If we do not put the graded chips, we cannot call it a bituminous concrete type of work; we should rather name it bituminous macadam.

In this latter type of work, my experience is that it is much better to put pre-mixed sand on top of pre-mixed stone chips rather than mix the two together. The pre-mixed sand seal provides a very strong hard non-abrasive skin quite fit to combat the heavily laden iron-tyre of bullock-carts.

Mr. G. B. Vaswani (Karachi):—This paper has been written by Colonel Sopwith and Mr. Griffiths. Colonel Sopwith, as you know, represents the Shalimar Tar Company, and Mr. Griffiths represents the Burmah-Shell. The meeting of these two gentlemen on one platform is like the meeting of the Ganges and the Jumna at the confluence. It is the Roads Congress that should be congratulated for having brought these two experts of different companies on one platform. Before the Roads Congress, I remember the days when the representatives of these two companies used to speak against each other. Now the time has come, with the efforts of the Roads Congress, when both can combine and give us a specification which would be useful to the benefit of all. The representatives of the asphalt company used to tell us to repaint the asphalt road with asphalt only, similarly the tar company desired that once the surface is tarred, it should be repainted with tar only, so as to maintain it a tar road. We found on our inspections that if the pre-mix done with tar was given a coat of Socony asphalt or Spramex, the results were satisfactory. This is the first paper written by the representatives of both the companies jointly and I hope that they will draw further specifications for the benefit of the engineers and give us expert advice and thereby save the tax-payers' money.

Mr. A. K. Dutta (Calcutta):—Bituminous Bonded surfacing on R.B.C. foundation is

- (1) Excellent for Bengal where stone ballast is very costly.
- (2) Excellent for Bengal in case of new roads where there is likelihood of settlement.

Mr. Vaswani said about the combination of the representatives of Messrs. Shalimar Tar and Messrs. Burmah Shell in producing the new paper on bituminous roads.

I come here with a suggestion where cement companies can co-operate with Tar and Asphalt Companies in producing a better class surfacing.

We saw on our first day, while inspecting the Calcutta-Jessore Road, about 6 inches Reinforced Brick Asphalt Concrete road, constructed in the year 1932 and its condition in 1939 i.e., 7 years afterwards is still ideal.

In case of new roads this construction is ideal as there is every chance of settlement of the foundation. Asphalt surfacing will yield with the settlement, whereas cement surfacing at top would then crack. I ask the writers of the paper their suggestions as to the most economical bituminous surfacing on R. B. C. foundations.

Colonel G. E. Sopwith (Author):—In introducing our Paper we gave our reasons why we have not given the necessary details to enable the production of a Code. I do not, therefore, propose to reiterate our reasons and will go on to Mr. Murrell's further criticisms.

(i) I personally do not believe that the system tried in Bihar of a primer coat of thin binder and sand with a second coat of a thicker binder and chips is the last word on the subject. It is too complicated a subject to deal with within the limits of this discussion but I definitely think that it merits constant thought and that it is still in the experimental stage and it might form the subject of a special paper before the next Congress.

(ii) Mr. Murrell has asked why we have omitted drag-brooming. Briefly, our reason for doing so was because the paper was written in general terms and was written in view of the existing work which is carried out in India. We are quite prepared to assist engineers who desire to carry out drag-brooming, but our own opinion is that equally satisfactory results can be obtained by hand-brushing by coolies. Although not mentioned in the remarks we have frequently heard this process called "mix-in-place". So far as we are aware, this term is used only for a different process involving the use of graders, wind-rowing, etc., and we think that to use the term for a totally different process is apt to lead to confusion and misunderstanding.

In our paper we have mentioned two-coat work and we do not fully appreciate Mr. Murrell's suggestion that we have ignored this type of construction, but there again we must point out that in our paper we have only briefly mentioned all types of construction. Both coats have their value according to local circumstances and these are so varied that a selection of method has to be adopted on individual merits.

We should like to point out that the use of the word 'Primer' is apt to lead to misunderstanding, as primer coats are usually light applications, while first coats are normally heavy ones.

(iii) Mr. Murrell refers to drag-spreading. This involves the use of more plant and we feel certain that Mr. Murrell will be the first to agree with us that the entire road development of India is held up through the lack of funds which prohibit engineers from purchasing materials and plant necessary to enable him and them to give the results which the general public expect. We could have said a lot about this method of construction but we felt at the time of writing the paper that it was unnecessary to enter into the details.

(a) The spreading of the large size chips first, rolling once and then spreading the small size and rolling to set is unquestionably a sound method and we regret we omitted a reference to this (while trusting that Mr. Murrell will accept the fact as an oversight and not a demonstration of our not being up-to-date).

We did not mention specifically the possibility of using sand and chips instead of chips only for cheapness. In our view a deeper principle.

is engaged. We contented ourselves with using the phrase "chips and/or sand". We have already referred to this in our comment on sub-clause (1) of Mr. Murrell's remarks.

Mr. Murrell was good enough to give us some rough comments on our paper some time ago and amongst them made the remark that "most of what will be known is known now". We do not think Mr. Murrell meant us to take this too literally, for that line of thought would be a partial deterrent to constructive thinking and no one can accuse Mr. Murrell of that. Speaking personally, I thought, when I left the service, that I knew quite a lot about road construction and maintenance. Now after having concentrated my mind solely on roads for 8 years, I am not so confident. While we certainly know a lot about existing methods we are, in my view, still far from perfect methods which only constant thought, research and practical experiments can help all of us towards. I think the really great changes in method that have occurred in the last decade are a fair proof of the correctness of this view.

Reply to the Comments made by Rai Sahib Tulsidas Banerji:—The practical point affecting a carpet of graded stone and a bituminous concrete is that, while a dense mixture of graded stone is necessary to obtain the best results, the grading must be very exact and be proportioned through all sizes from the largest down to stone dust. This can only be done if very elaborate and expensive stone-breaking plant exists and this is not financially possible in India to-day, except in very large cities. We have to rely on rough and ready grading, which is all that hand-breaking can produce. If the stone is very hard and not brittle, it is a very satisfactory method but otherwise, there is the fear of crushing, because the mass is not dense enough. Hence the introduction of sand in place of the small particle, as by this method, the voids are completely filled. It is true that more binder is necessary but the use of sand, if cheap, instead of small particles, which are usually expensive, more often than not, balances the expense of extra binder and the finished cost rarely exceeds that of a pre-mixed aggregate carpet. Incidentally, if a graded carpet is constructed where a mechanical stone-breaking plant is in existence, the binder used is nearly as much as in constructions such as Sheltercrete or Tarcrete and the cost much greater.

The sand acts partially as a cushion and prevents the breaking of stone when the latter is brittle. The sand is also, by its nature, hard and in actual practice takes, and is capable of taking, traffic without destruction of the metal particles; in other words the wearing is either less or even.

The quantity of binder is carefully designed to give a thin film on each particle of stone and sand. No excess to cause tacking, therefore, exists.

The question of absorption or reflection of artificial light by road surfaces is of great importance. A study of technical publications for some years past will show that it is being investigated in America, Great Britain

* These comments were received by post and are printed under Correspondence on page 22 (1).

and on the Continent in all its aspects. So far, though considerable progress has been made, really satisfactory conclusions have not been reached. Such investigations are very expensive and, in the present stage of road development in India, it would appear wise to watch the results of investigations elsewhere and to adapt to Indian conditions methods which may be satisfactorily evolved.

Slipperiness is the bane of all road-users and constant research into the best method of producing non-skid surfaces is carried out and results incorporated in actual construction in India as well as in other countries.

CORRESPONDENCE

I. "Comments by Rai Sahib Tulsidas Banerji, M. E. S., Jubbulpore, received by post.

I congratulate the authors for their very excellent paper covering practically all the essential features of a good road. There are, however, one or two points, which should be clarified.

Regarding pre-mix macadam, it is stated on page 7 (1) of the paper 'that the strongest type of construction which could be laid out would be one, where all the voids are filled, and the spaces between the stones packed tight with a material which prevents the stones from moving. Bituminous concrete is this type of construction and answers the requirements given above. By taking one size of stone and pre-coating it with a bituminous binder, to which is added pre-coated sand, a strong dense carpet is obtained. In view of the fact that no small stones are used, there is no danger that they might not go into their proper place between the big stones.....The coated sand makes an excellent material for filling the voids.....'.

The idea apparently is to have a dense mixture. But it is a well known fact that the densest mixture occurs only with stone metal of different sizes so graded that the voids of each size are filled with largest particles going into them and the bitumen provides only a thin film, just enough to firmly bind the stone particles together. Voids in similar sized particles are very high averaging over 42%. This equally applies to sand, which in turn means larger quantity of bitumen. Then, as the voids will be filled with coated sand, it would be interesting to know its actual effect on the road surface. Will the sand wear uniformly with metal or would it produce a wavy surface? How would the excess bitumen react on the road surface? It is very likely that it would exude upon the surface by the action of heat and traffic and tend to make the road slippery.

Now that the motor vehicles are daily increasing in number and craze for speed is on the ascent, control of speed is getting more and more difficult. Roads will now have to be made to suit the speed. It, therefore, follows

* Colonel G. E. Sopwith's reply to these comments appears on page 21 (1).

that any measure, however slight, which affords increased safety on the road, merits consideration.

Slipperiness helps skidding, which may result in fatal accidents. The aim should, therefore, be to provide non-slippery surface, mosaic in appearance and skid-resistant at high speed.

Another aspect of bituminous roads, which requires investigation, is the extent to which they absorb or reflect artificial light such as powerful head light of a motor car. It is a matter of common experience that wet and smooth surfaces give increased glare. In wet roads, perhaps the film of water covering the surface acts as a reflector, and breaking this up by provision of a suitable surface texture might reduce the glare of approaching head lights. But to arrive at scientific data, the cause of and remedy for slipperiness and glare should be carefully studied and tests carried out under varying conditions prevailing in the country.

II. Reply by Colonel G. E. Sopwith and Mr. W. A. Griffiths (Authors) to the comments^{*} of Mr. N. Das Gupta.

Mr. Das Gupta's remarks are of interest and value. Taking the points in order :—

(a) *Treatment of kankar etc.*—Our paper deliberately did not go into all the different methods of treatment, designed as it was to elicit constructive criticism. A reference to the paper will show that we gave well-burnt brick as an alternative to stone metal. The method suggested of pre-mixing the brick metal and super-imposing pre-mixed sand is interesting. The reason we suggested 3-inch thickness was to get less pressure per square foot on the original surface and our experience suggests 3 inches as being better than 2 inches unless the subgrade is really solid. It appears to us that the solidity of the subgrade is the ruling factor for depth of metal.

(b) *Reasons for failure of water-bound roads.*—We are afraid we took for granted that members would appreciate that crushing of the stone metal itself is an obvious reason for failure and we endeavoured to make clear that if the stone is liable to crushing some method of cushioning is of vital importance.

We also assumed that members would realise that waterproofing is a vital principle and that it is automatically produced by bituminous treatment but we should perhaps have said so definitely.

(c) *Classification of types of construction.*—The suggestions can be considered by the Technical Sub-Committee and a standard eventually laid down. We are not, however, sure whether it is wise not to differentiate between thin and thick carpets, while item (2) as given by us refers merely to pre-mixing the chips or gravel for surface treatment and is based on somewhat different principles than those of carpets.

(d) *Funds at disposal.*—We agree that "most economical" is a better term than "Cheapest and best".

* These comments are printed under Discussions on pages 16 (I) to 18 (I).

(e) *Size of stone for bituminous concrete.*—This is a good illustration of the difficulty of writing a joint paper. Actually when using Tar, a degree of grading is adopted. It would appear that manufacturers of bitumen do not always adopt the same specification.

(f) *Specification for bituminous concrete.*—Mr. Das Gupta favours laying the pre-mixed chips and super-imposing the pre-mixed sand instead of mixing the two together first. We do not think that the essential principle of completely filling the lower voids is certain to be fulfilled by this method and we think that there is danger of collapse if the stone is not very hard and so crushable under very heavy traffic.

The criticism is constructive and, therefore, valuable and worth consideration by the compilers of a Code, if and when the latter is written. One vital point in such a Code is, in our view, the complete bifurcation of the sections dealing with Bitumen and Tar after a preliminary section embodying specifications common to both for preliminary treatment of surfaces before application of the bituminous products. The details of a Code and the extent to which it is now possible to produce one is for the further consideration of the Technical Sub-Committee, who would put up their opinion for the decision of the Congress.

PAPER No. P.

REVITALIZATION OF TARRED OR BITUMENED SURFACES BY MIX-IN-PLACE METHODS USING CUT-BACK ASPHALT.

BY

CAPTAIN R. C. GRAHAM, R.E.,
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Peshawar Cantt.

This Paper deals exclusively with an operation actually carried out in Peshawar, North West Frontier Province, and, as such, is a description of that work and is not meant as a rule laying down how similar work should be carried on elsewhere. Conditions vary in different places but where metal and *bujri* are cheap the Paper may be taken as a guide for the type of work carried out.

The author has been faced on a number of occasions with the problem of how to deal with disintegrating tar and bitumen miles laid in the earlier years when such processes were first applied. It appears that in the North West Frontier Province (and quite possibly in other parts of India too—though the author has no knowledge of this) such surfaces often break up badly. The probable reasons for this have been looked into in detail by the author; they are numerous and open up a problem quite separate to the subject of the Paper. The chief reason appears to be overheating of the binder, while laying, by an ignorant staff. The fact remains, however, that the binder loses its viscosity (perhaps better described as its elasticity), dries out and breaks up under traffic into dry pieces which powder easily in one's fingers. When this starts, the road surface rapidly disintegrates forming many pot holes.

The question then is—what should be the remedy or remedies? They are numerous but the four main ones may be described as :—

- (1) Removing the road surface, re-metalling and surfacing.
- (2) Scraping off the top surface, levelling up the existing metal by adding very small quantities of half-inch gauge metal and surfacing.
- (3) Keying the existing surface (or removing it completely) and adding a premix carpet.
- (4) Adding a mix-in-place process to the existing surface, having first filled in the pot holes thoroughly.

Processes 3 and 4 should only be applied when the engineer in charge is quite satisfied that the material in the existing surface (this does not include the road base and the old metal below the surface each of which is assumed to have reached its final settlement) will bear the pressure of the traffic as applied to the new surfaces to be added, *i.e.*, he should be quite certain that the old surface will not crush under load and so cause waving and depressions in the new surface. If the latter occurs the life of the new surface is obviously shortened.

Concrete is definitely not mentioned because, unfortunately, it is too expensive for the North West Frontier Province—whose finances are meagre.

The Paper deals with the Saddar Road ; this runs through the shopping centre of Peshawar Cantonment. The average daily intensity of traffic is about 200 tons per foot.

This may not appear a large figure but, in actual fact, owing to its continual stopping and starting when visiting shops, the traffic does exert a very much higher road wearing factor than a similar intensity would on an open road. In addition various building operations seem always to be in hand in the nearby bazaar and a considerable number of heavily laden bullock-carts (with narrow wheels) carrying bricks pass to and fro.

In 1933-34 the surface was re-treated with a cold bitumen emulsion ; the blinding used was half-inch local nullah *bujri* which is cheap and also hard wearing. This stood up well for two years but, in 1936, the surface began to show signs of wear and patch repairs became necessary. These patch repairs unfortunately could not keep up with the wear and early in 1937 it was obvious that special repairs were necessary.

After due consideration it was decided that a mix-in-place treatment would be the most suitable on the grounds that other processes, like re-metalling, would take too long and would, therefore, interfere too much with the shopping traffic.

Work was carried out during the end of September and the beginning of October 1937. The weather was fine with no rain at all. The average maximum day shade temperature was 94.5 degrees Fahrenheit.

Before the materials were collected at site, it was decided to order a special drag broom which latter is essential in the process. It has been found from past experience that locally made drag brooms are not efficient but a very suitable one was procured from Cawnpore, *vide* plate on page 5 (p). It is interesting to note that the brushes are very easily replaced by virtue of the fact that they are bolted into the cross beams.

First, the road surface was thoroughly well cleaned and, concurrently with this, all depressions in the surface itself and all pot holes were cleaned out. They were then painted all round with cut-back Asphalt. The latter material is a proprietary article which is applied cold. After this application, the depressions and pot holes were filled and rammed up to the existing road surface level with three-fourths inch gauge chippings mixed with crushed stone and cut-back Asphalt at the following rates :—

Half cubic foot Chippings broken from 6 inch blue limestone River boulders.

Half cubic foot Crushed stone. This was obtained from the small pieces which came from the breaking of the chippings. About $\frac{1}{2}$ to $\frac{1}{4}$ inch gauge.

Four pounds of Cut-back Asphalt.

The road surface was now sufficiently level for the whole of it to be painted with cut-back Asphalt prior to the addition of the stone material for

the premix. The cut-back Asphalt was applied at the rate of twentyfive pounds per hundred square foot. The work was done in strips of one hundred and fifty feet at a time for the whole width of the road which is sixteen feet. When this painting was complete, three-fourths inch gauge chippings were spread at the rate of four cubic feet per hundred square foot of the road surface.

While this was being done, a second length of one hundred and fifty feet was being painted similarly to the above. This was completed with chippings in due course making a total of three hundred feet ready for mix-in-place work.

The three hundred feet was then subjected to the drag broom which was originally drawn by a motor car. The object of this was to demonstrate to the steam road roller driver how the drag broom should be applied as it is essential to impress on the workmen that the drag broom must neither be drawn too quickly nor jerkily. After a short demonstration the drag broom was attached to the steam road roller.

The object of the broom was to turn over these chippings on top of the painted surface until such time as they became fairly coated with the cut-back Asphalt; this is recognizable as it has been found that with the quantities applied this occurs when the whole of the chippings appear black. While this is being done, the effect of rolling is so slight as not to compact the material until it has been properly coated. When this occurred, light rolling was started; this was just sufficient to compact the material slightly.

When this rolling was complete, the crushed screenings from the chippings together with one-quarter inch *buzri* (approximately at the rate of half the quantity of chippings already put on) was sprinkled over the road surface with a view to filling any remaining voids. When this had been done, further drag brooming and hard compact rolling were carried out simultaneously.

This was the first day's work. On the next day the surface was blinded with coarse sand which was rolled in tight and the road was immediately opened to traffic.

Rolling in each case was done with a ten ton roller.

The work was continued throughout the whole length of the road which was 4,700 feet.

A small point which might be of interest is the following:—

In one portion of the road, as it existed, the camber was excessive and to get rid of this the three-fourths inch gauge chippings were increased from four to six cubic feet per hundred square feet with the corresponding amount of cut-back Asphalt and the extra thickness was laid on the outside edges of the road. Drag brooming and rolling was applied as before and the surface was flattened successfully to counteract this camber.

In conclusion it has been found that in Peshawar District this type of work is very much cheaper than remetalling and surfacing or than using a three-fourths inch premix carpet.

COSTS.

1. The cost of one-quarter inch *bujri* per hundred cubic feet is Rs. 10/-
2. The cost of three-fourths inch chippings per hundred cubic feet is Rs. 15/-
3. The cost of coarse sand per hundred cubic feet is Rs. 8/-

For a 16 feet wide road the comparative costs are :—

1. Mix-in-place Rs. 6/- per hundred square feet.
2. Remetalling and surfacing (Two and a quarter inch consolidated) Rs. 7/- per hundred square feet.
3. Three-fourth inch premix Rs. 7/8/- to Rs. 8/- per hundred square feet.

The work has been extremely successful but the author would like to state here that there are certain points which need careful attention. They are :—

1. The drag broom must be efficient.
2. The material must be thoroughly well mixed up before final rolling.
3. No dry patches must be left on the road.
4. If there is any tendency for bareness to occur in places whilst drag-brooming, the work must be stopped and such places must be painted with cut-back Asphalt and additional chippings and *bujri* put on before the work is allowed to continue.

PHOTOGRAPHS.

Photograph No. 1 shows the road surface as it began to disintegrate. There is only one pot hole shown ; it is in the centre of this photograph. This was about six inches deep at the time. No other photographs are available to show the state of the road when work was commenced.

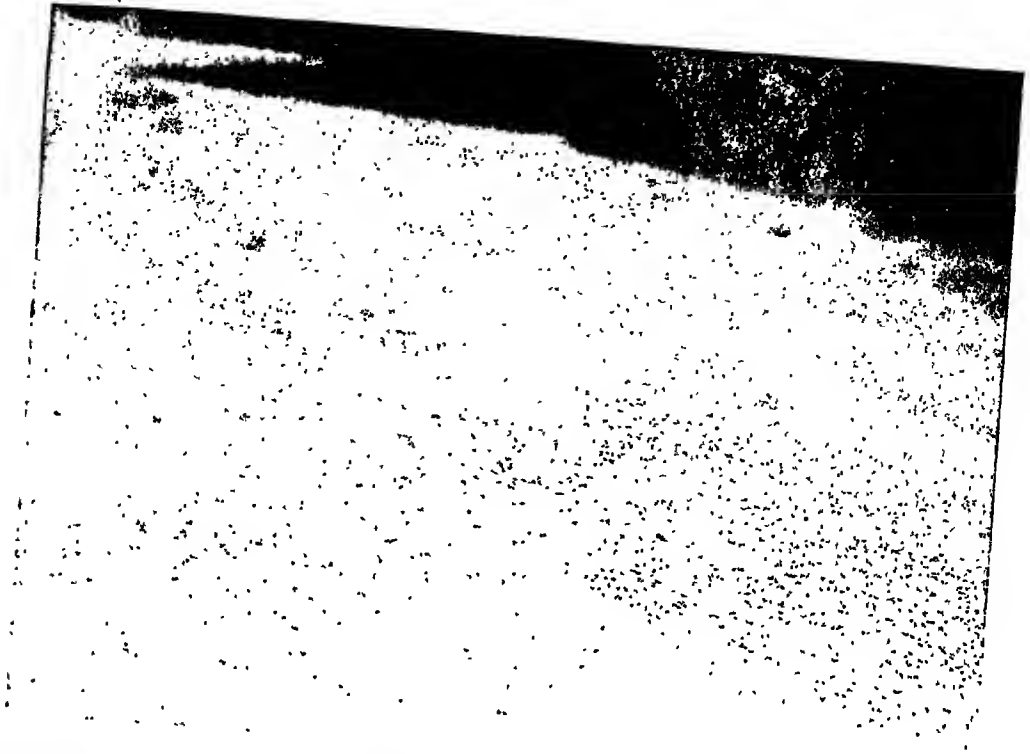
Photographs Nos. 2, 3 and 4 show the finished mosaic surface which is standing up to traffic very well. These photographs were taken seven months after the work was completed and considering the traffic going over this surface it has stood up very well indeed to wear.



No. 1 MIX-IN-PLACE
Saddar Road, Peshawar. Disintegrating Surface before mix-in-place was applied.



No. 2 MIX-IN-PLACE
Finished surface. Saddar Road, Peshawar.



No. 3 MIX-IN-PLACE
Finished surface. Saddar Road, Peshawar.



No. 4 MIX-IN-PLACE
Finished surface. Saddar Road, Peshawar.

DISCUSSIONS ON PAPER No. P.

Mr. W. Lawley (N. W. F. Province):—Captain R. O. Graham is very sorry he is unable to be present to day; he has however left the P. W. D. and is now at the War Office, London. He has asked me to introduce his paper. Unfortunately, I did not see any of the work which forms the subject matter of his paper, during execution. I have however, on my way to Calcutta, inspected the Saddar Bazar Road in Peshawar. I was told that six months or so after the mix-in-place surfacing was done, the road surface was uneven and rather dry. It was decided to patch and surface-paint this with 15 pounds of cutback asphalt per 100 square feet, blinded with hajri $\frac{3}{8}$ inch to $\frac{1}{2}$ inch. The cost of this surface painting was Rs. 1/- per hundred square feet. The surface of the road now is very good.

In July 1938, this mix-in-place method of treating a brittle and devitalized surface was adopted for mile 273 of the Grand Trunk Road, just outside Peshawar City. The traffic there is very heavy. The specification was altered slightly, 30 pounds of cutback was used per 100 square feet; 25 pounds painted on the surface, then $6\frac{1}{2}$ cubic feet of $\frac{3}{4}$ inch chippings per 100 square feet spread, and the drag-broom used as before. The remaining 5 pounds of cutback was sprinkled on the surface afterwards in places where the stone had not been thoroughly coated. Two cubic feet of hajri and sand was used as blindage. The result at present does not appear too promising. It seems that in places a distinct layer has been formed between the $\frac{3}{4}$ inch chips, and the blindage subsequently applied. This upper layer is, in isolated places, peeling off, leaving the $\frac{3}{4}$ inch layer underneath sound and compact. This could probably have been avoided by blinding with sand instead of hajri. This road is now slightly bumpy and will be treated with another surface coat of $1\frac{1}{2}$ gallons of cutback per 100 square feet in the early summer, to correct this.

The reason for the uneven surface after treatment in both cases, is probably due, to doing patch repairs to the original road surface too soon before re-surfacing. Captain Graham has given a figure of Rs. 7/- per 100 square feet for metalling and surfacing in his table of comparative costs. This figure may be misleading, as we do surfacing on a newly metalled mile in two parts i.e. surfacing soon after metalling and then another surface coat within 6 months. He is referring to the cost of the initial surface coat with metalling. The complete cost would be Rs. 10/- per 100 square feet.

With these introductory remarks I have great pleasure in presenting Captain Graham's paper.

Mr. S. Bashiram (Punjab):—I have just a small quarrel with the author and that is about the title of his paper. The term "Revitalization" would in this case appear to be an entire misnomer. With the title as it stands, one would naturally conclude that the object of the method adopted was to get a fresh surface from the old to which it was allied by some method of rejuvenation—a sort of monkey-gland treatment which infused a fresh lease of life to the surface as it originally existed. Actually we find that all that was done, was to re-lay a brand new surface on the original, which certainly cannot be called a "Revitalization" process.

Mr. S. A. Amir (Bihar):—My aim in taking part in discussions on this paper is not to offer any criticism but to have a few points cleared up and to acquaint you of a few things which were experienced in carrying out similar work as an experiment on certain roads in the Hazaribagh Division.

In method No. 2 suggested by the author of the paper for dealing with disintegrated tarred or bitumened surfaces, he mentions "Scraping off the top surface, levelling up the existing metal by adding very small quantities of half-inch gauge metal and surfacing". How should this be achieved if anything more than simple repainting after removal of the perished surface is meant?

In connection with method No. 4 for filling in pot-holes in advance, it is suggested by the author to clean the pot-holes and depressions and paint them all round with cutback asphalt and then to fill them up with pre-mixed chippings (4 pounds of cutback asphalt to a cubic foot of graded chippings). The pot-holes' surface being naturally rough and in a cavity there is a risk of its retaining more of cutback asphalt than in painting a level and a smooth surface and this combined with the asphalt in the pre-mixed chippings at the rate of 4 pounds to a cubic foot is, as experience shows, liable to give spots too rich in asphalt which will develop in course of time into bad bumpy spots in a surface which may otherwise have excellent riding qualities. In photograph No. 4, the black spots may be indications of such bumpy spots developing in the road surface. I would suggest that the tack coat might be given with two parts of cutback asphalt, like socofix, with one part of kerosine and in the preparation of pre-mixed chippings as little of cutback asphalt should be used as possible.

It is said that after such initial patching up the road surface became sufficiently level. This being so, and considering that only 25 pounds of cutback asphalt and 4 cubic feet of $\frac{3}{4}$ inch chippings were used, one wonders if at all drag-brooming was necessary and why simple painting and laying chips would not have been sufficient. Evidently adding of the 2 cubic feet of hajri per 100 square feet subsequently was for filling the interstices between the bigger chips and not for correcting the level of the road. Only in the portion of the road where camber is said to have been excessive, requiring corrections, and for which 50 percent more chips and cutback asphalt were used, the drag-broom seems to have been indispensable.

In my opinion unless one has to deal with surfaces which are not true and have bumps and depressions or faulty camber, giving bad riding qualities, mix-in-place surfacing would un-necessarily require more expense than straight-forward painting work.

As stated before, some experimental mix-in-place work with drag brooms was tried in Hazaribagh Division in May last year on a 1936 bitumen surface and a 1929 consolidated water-bound surface which was rough but not corrugated and had excessive camber. Main feature of the work was the same as described in the paper but following additional details may be interesting and useful to those who may have to do any such work in future:—

(i) The 1936 bitumen surface (9 feet wide) had depressions and had bumps giving bad riding qualities. Cutback asphalt was applied at the rate of 20 pounds per hundred square feet, and 5.7 cubic feet chips were laid

(3.4 cubic foot of $\frac{3}{4}$ inch chips on $2\frac{1}{2}$ feet strips on the sides and 2.3 cubic feet of $\frac{1}{2}$ inch chips in the centre) in 100 square feet area of the road. Over this there was a further application of cutback asphalt at 8 pounds per hundred square feet, with the help of pouring tins, with lower half of one side perforated and drag-broom was worked over it to mix-in-place and level up the surface. Application of binder in two instalments means more time and cost and I am not sure if it gave sufficient advantage to be preferable to the single instalment application as done by the author of the paper.

(ii) In working the drag-broom it was found advantageous to make 2 or 3 persons sit over it in the initial stages to add to its weight for being more effective in making chips to roll and get coated with the binder in place.

(iii) At original depressions, at sides and where sufficient chips had not been initially put in, the drag-broom was not touching and hence more chips had to be laid and additional cutback asphalt was poured over it with the perforated tins.

(iv) During rolling without drag-broom attached, bare spots appeared and had to be filled up with $\frac{3}{4}$ inch pre-mixed chips (3 pounds to one cubic foot), but work did not have to be stopped for this as is suggested by the author to be necessary.

(v) Finishing was done by laying and rolling $\frac{3}{4}$ inch to $\frac{1}{2}$ inch chips at the rate of 1 cubic foot followed by sand at the rate of 1 cubic foot per 100 square feet and the road was opened to traffic after 48 hours.

(vi) In all, 31 pounds of cutback asphalt, 7.9 cubic feet of chips, $\frac{3}{4}$ inch to $\frac{1}{2}$ inch gauge, and 1 cubic foot of sand were used per hundred square feet. Cost worked out to Rs. 4/8/- per hundred square feet against Rs. 3/4/- if simple painting with cutback and chips would have been possible and if levels and excessive camber were not to be corrected.

(vii) In mentioning the above figures, I wish to stress that where levels have to be corrected, consumption of more materials than in simple paint work, is indispensable and without the help of drag-broom these could not be properly laid on the road.

In the case of the old water-bound surface, work was done exactly in the same manner except that 30 pounds of cutback asphalt was laid on the road surface followed by 15 pounds over the chips per hundred square feet. This increased quantity of binder was obviously for allowing for penetration within the water-bound surface in the absence of any initial primer coat.

Incidentally it may be mentioned here that with a view to reduce cost, on a portion of the water-bound surface, Road Tar No. 2 at 82 pounds per hundred square feet was laid in place of the first instalment of cutback asphalt and over it chips were laid and above these cutback asphalt (15 pounds per hundred square feet) was applied. It was remarkable, while drag-brooming, how long the mixture of Road Tar No. 2 and cutback asphalt remained soft and it took so much longer to sufficiently

stiffen for being rolled compact that its success looked doubtful at the time. But after all, this turned out as good as the other stretch done with cut-back asphalt alone and the cost of the former worked out to Rs. 5/- per hundred square feet against Rs. 5/13/- in case of the latter. Probably even smaller proportion of cutback asphalt would suffice to enable mix-in-place with Road Tar being carried out and this should give a still lower cost. This is proposed to be further experimented upon, but it is still to be seen which of the two stretches wears better, i.e., the one done with cutback asphalt alone or the one done with a mixture with Road Tar No. 2.

In conclusion, I think there are great possibilities of improving sealed surfaces with bad riding qualities or surfacing roughish water-bound surfaces without reconsolidation with the help of such mix-in-place treatments with economy.

Mr. K. G. Mitchell (Chairman):—Does anyone else wish to speak on this Paper?

I do not know whether Mr. Lawley would like to reply to the comments.

Mr. Lawley:—Replying to Mr. Bashiram's criticism of the title of the paper, I would refer him to para (2) in which the author has explained that the problem facing him has been how to deal with disintegrating Tar and bitumen milés, carelessly laid in the past. The operation described in the paper is intended to put new life into these old surfaces without which it would not be practicable to put a new wearing surface on top of them. Without this revitalization process the alternatives would be as described in paragraph 3, items (1), (2) and (3).

I should like to thank Mr. S. A. Amir for giving us an account of his experiments in using cutback asphalt for surfacing by mix-in-place methods. He appears to have used this method as an alternative to pre-mix work; while the author's object in using mix-in-place methods was not as an alternative to pre-mix, but in order to liven up or revitalize the old surface of the road, which at the same time was not true, and had excessive camber.

The author's intention in method (2) was to remove the perished surface and then do simple repainting.

I agree with Mr. Amir's remarks regarding pot-holes. In actual practice these did tend to become too rich in asphalt. I consider that pot-holes should be separately treated about 6 weeks before the main surfacing work is commenced. I would prefer treating the pot-holes with a pre-mix, as the need for revitalization in such spots does not hold.

—Regarding the criticism as to why drag-brooming was used instead of simple painting, when the road surface was, in the words of the author, "sufficiently level for the whole of it to be painted with cutback asphalt". The author, I think, means that the surface was reasonably level, but not true to camber, nor had minor depressions been removed. By

drag-brooming the whole surface was made accurately level and true to camber; whereas simple painting would have reproduced on the finished surface the minor irregularities underneath not corrected by the patching. I agree that this mix-in-place surfacing should not be used in place of simple painting, except when the surface is not true and gives bad riding qualities.

Mr. K. G. Mitchell (Chairman):—I am sure you will all join me in offering our very hearty thanks to the authors of these Papers, and in particular to Col. Sopwith and Mr. Griffiths. Mr. Murrell has pointed to the need of standard specifications and has referred to the practice in other countries such as the U. S. A. and Australia. But, as far as I am aware, in both those countries the specifications are drawn up by the State authorities, and although they may follow general standards of practice, they are peculiar to the localities. At this Congress, we have had three Papers which were written as contributions to the eventual standard Code of Practice for the whole of India, leading from the layout of roads, earth-work, and consolidation of macadam to practice in regard to bituminous surfacing and crusts. My personal feeling is that we are still progressing in bituminous practice upon which it is, therefore, difficult to dogmatise, but that the principles of layout, earth-work and ordinary metalling are sufficiently well-established to be standardised without question. As far as I am aware, there is no text-book dealing with the more elementary or basic principles of road construction, other than the bituminous surfacing, to which people can refer and I think that, even if we find it impossible to codify bituminous practice, the Code of Practice for the rest will be invaluable. Without wishing to be in the least critical, I can say from my own experience in wandering about different parts of India that I often find things going wrong in ordinary road layout and construction, particularly such as the providing of unnecessarily high banks and defects in the laying of soling which render the standard Code of Practice necessary.

As regards bituminous work, my personal suggestion is that, while we should not ignore progress which is being made in the improvement of materials, the time has come to concentrate, if possible, on one or two definite types of construction and to reduce the number of specification in use. In that connection I am reminded of *Aesop's Fable* about the Cat and the Fox and suggest that one or two well-tried specifications may be preferable to too great a variety.

Even for a standard Code of Practice for all the work up to and including water-bound macadam, I do not know if it is possible that a small committee, with experience necessarily limited to practice in one part of India or another, can attempt to prescribe. That is even more so when we come to bituminous practice where there are differences in results in different parts of India which we cannot readily explain. I think, therefore, that our Technical Sub-Committee should be more representative than it is of different parts of the country and at the business meeting tomorrow, when we consider the formation of committees, this aspect should be borne in mind.

In conclusion I repeat that we owe a very great debt of gratitude to the authors of these Papers.

PAPER R.

Mr. R. A. Fitzherbert (Chairman):—The last paper for discussion is Paper R—"A serious failure in the painting of a steel highway bridge". I would call upon Mr. Murrell to introduce this paper.

The following paper was then taken as read:—

PAPER No. R.

A SERIOUS FAILURE IN THE PAINTING OF A STEEL HIGHWAY BRIDGE.

BY

W. L. MURRELL, B.C.E. (Melb.), A.M. Inst. C.E.,
Superintending Engineer, Chota Nagpur Circle, Bihar.

It is not so pleasant to proclaim one's failures as it is to broadcast one's successes, and my object now in parading the skeleton that has come to my cupboard is to render help to brother engineers by indicating a very real pitfall.

Also, if the dissemination of information through the Indian Roads Congress can prevent some wastage of the tens of lakhs of rupees of public money that are spent annually on the painting of steel bridges in India, then those on whom the continuance and development of the Congress depend, may form an even higher estimate of its utility.

For obvious reasons, I cannot mention the name of the bridge or the brands of paint concerned.

The bridge, which is a large one of the deck type, had not been painted since 1925-26 and it was found, late in 1936, that corrosion had commenced, and that cleaning up and painting were necessary.

I approved the following specification:—

- (1) The entire steelwork of the bridge shall be thoroughly scraped, cleaned, and painted 2 coats black bitumastic on one coat of red lead paint.
- (2) The second coat of black bitumastic paint to be applied two months after the first coat.
- (3) Proper paint brushes to be used and each coat of paint to be approved in writing by the Executive Engineer before the next coat is started.
- (4) Painting to be done in the dry weather only.
- (5) Paint to be used shall conform with the Indian Railway Board Standard Specification.

The priming coat of non-setting red lead up to Indian Railway Board Standard Specification, was commenced early in February 1937, and finished by the middle of the following month.

The second and the finishing coats were commenced in the middle of February 1937 and finished early in the following June.

This period represents the end of the cold weather and the whole of the hot weather. There were about 4.5 inches of rain in each of the months February and May but there was no rain at all in March and April.

The contractors for the work were a very experienced and reliable firm of structural steel engineers, and the supervision by the Public Works Department was even more efficient than usual.

There seemed no reason, therefore, why the work costing Rs. 16,550/- should not prove a complete success. Instead, there was a bad failure.

In December 1937, only six months after the third or finishing coat had been completed, it was noticed that the red of the priming coat was clearly visible in parts, and that some of the remaining surface had lost its jet-black appearance and was turning brown.

These phenomena are now seen in many places on the bridge irrespective of whether the painted surface was protected from rain, sun or wind.

Close inspection shows that the priming coat of red lead is in excellent condition and completely homogeneous. In no case has it been penetrated by the bituminous upper coatings. Also, in no case has the red lead invaded these upper coatings. Testing was done by scraping with a pen knife.

The next point for consideration is that another large bridge was painted by the same firm of engineering contractors in 1927. This is a through type bridge, and the very high trusses were less easy to paint.

The painting here also was one coat of red lead priming with two coats of bituminous paint as covering to the priming.

Apparently, the specification was the same as for the former bridge, and the work was done at much the same time of the year.

On this latter bridge, however, the painting done in 1927 was a complete success and it has been decided to repaint it only in the present season.

Below is given a copy of the results of analysis of the respective covering bituminous paints :—

Test.	Paint used on the through bridge where painting was good.	Paint used on the deck bridge where painting failed.
Volatile portion (Distillate up to 150°C) ...	20.2 per cent.	37.5 per cent.
Portion soluble in petroleum ether after driving away the volatile portion ...	27.5 „	38.5 „
Portion insoluble in petroleum ether but soluble in benzene ...	39.5 „	19.2 „
Insoluble Carbonaceous ...	9.0 „	traces
AM ...	0.05 „	traces
Vegetable oil ...	absent	absent
Smell ...	Coal tar smell	Kerosene smell.
	Coal tar base	Petroleum base.

Considerable trouble was taken to obtain the views of experts, on this failure.

The contractors for the painting helped by having analyses made in their research department in Calcutta, a reference was made to the Alipur Test House and, with the permission of the Chief Engineer of the Public Works Department, Bihar, the matter was referred to the Corrosion Committee of the Iron & Steel Institute, England, and to the Association of Paint, Colour & Varnish Manufacturers in India.

The reason why some bituminous paints fail whilst others stand fast may apparently be summed up as follows :—

Straight bitumens, dissolved in petroleum spirit without additional binding material, when applied to surfaces exposed to much heat and light, readily powder on the surface.

This powder is soon removed by rain or wind, especially wind bearing fine sand from the river, thus exposing fresh surfaces to the same effects.

This process continues until the whole of the film disappears, leaving the undercoat.

The same thing would not occur with a bituminous paint prepared from bitumen and a coal-tar base as there is in such paint a large proportion of non-volatile material which acts as a plasticiser and keeps the finish in a tougher and more elastic form.

That is the main point desired to be expressed in this paper.

The trouble is that there are a number of firms of high repute in India today who are making bituminous paints without the requisite non-volatile plasticiser, and the specification is accepted by even the highest authorities except, I believe, the Indian Railway Board.

It is understood that the manufacture throughout India of this bituminous paint, unsuitable thus for bridge painting, is probably several hundred tons weekly.

It would appear that such paint is unsuitable for covering to steel work in India, except under water.

There is another rather important difference in the two kinds of bituminous paint.

With the former paint, that with the petroleum base, it is a little difficult to get a good surface in awkward places where the paint cannot be applied quickly. The reason for this seems to be that the solvent in the second coat tends to dissolve the bitumen deposited in the first coat.

With the tar base paint, the non-volatile plasticiser again appears to come to the rescue. It, or something else in the deposited first coat appears to change on drying in the air, so that, when the second coat of bituminous paint is applied, the solvent in it cannot affect the bitumen in the first coat.

Here there appears to be some similarity with the case of an ordinary oil paint. The vehicle in the second coat of ordinary oil paint cannot disturb the pigment in the first coat because the pigment is held in place by the dried linseed oil in the first coat.

The dried linseed oil thus appears to act in the same way as the non-volatile plasticiser of the tar base bitumen paint, *i.e.* as a reliable binder.

The final point then arises:—What is a suitable covering paint for the now world-wide accepted red lead priming?

Here I quote Dr. J.C. Hudson, Official Investigator to the Corrosion Committee.

"The work of the Corrosion Committee has shown that for general purposes few, if any, paint combination give better results than red lead paint followed by red oxide paint and, although bituminous paints might also prove perfectly satisfactory, there is always a certain amount of risk unless their composition is carefully checked."

Personally, I have continued, except in the painting of steel trough plates, to specify bituminous second and third coats over red lead primer, insisting on proper analysis to prove the existence of the non-volatile plasticiser, the man on the spot insisting on the coaltar smell.

The red oxide paint has the advantage that, by mixing a little red lead with the red oxide in the second coat, one can get a colour different from that of the third coat so that, with doubtful contractors or supervision, one can easily know that the third coat has actually been done over the whole surface meant to be painted three coats.

This trick of the trade is not so easily practised when the second and third coats are bituminous paint which, of course, is invariably black; though certain unscrupulous firms do sell cheap coloured paints as bitumastic or bituminous paints.

The only objection I personally have against red oxide as a finishing coat is that it, being red, tends to camouflage corrosion of the steel rather than show it up, as a black finish does.

As regards the painting of steel trough plates for bridges that are to carry water-bound macadam, it seems that there is no paint to equal red lead. As a rule, small stalactites of minerals form on the lower side of the trough plates and on the cross beams after some years. The stalactites appear to be made up of chemicals leached out of the concrete filling over the trough plates.

If the vicinity of the stalactites be examined it will be found that corrosion has started wherever a bituminous paint has been used, even one with a tar base. But where red lead has been used there is no, or very little, corrosion.

The real purpose of this paper, however, is to invite the attention of members of the Indian Roads Congress to the absolute necessity for having the non-volatile plasticiser in any bituminous paint.

Mr. W. L. Murrell (Bihar) :—By way of introducing my paper I would like to say that, since submitting it, something more has occurred which might well be mentioned now.

Naturally, it has had to be decided how the defect will be remedied.

Obviously, the unreliable paint had to be removed, and it has been found that the best way of doing this is by rubbing it off with kerosene and rags, at a cost of from Rs. 1/4/- to Rs. 1/8/- per hundred square feet.

Paint experts stated that, after the cleaning, there would be still enough of the bituminous paint to bleed through any linseed oil paint, and make it look unsightly in future.

These experts recommended that aluminium paint should be used over the cleaned original red lead, as it is the only paint through which the residual bitumen will not bleed.

Owing to the high cost of two coats of aluminium paint, it has been decided not only to take off the remains of the unreliable bituminous paint, but also to scrape off a good deal of the priming coat of red lead.

When the surface is free of bitumen the whole will be repainted with one coat of red lead and two coats of red oxide paint of slightly varying shades.

The second matter I would like to refer to, is the recent publication, by the Indian and Steel Institute of the First Report of the Protective Coatings Sub-Committee.

I have suggested to the Secretary of this Congress that a copy of the Report be included in the Congress Library. There certainly should be a copy in the libraries of all Engineering Schools and Colleges in India. Every Engineer with a painting problem should read this Report.

The Report does not discriminate between bituminous paints with a tar base and those with a petroleum base; but it shows generally that bituminous paints are not nearly so trustworthy as the lead and oxide paints.

When we were inspecting the Alipur Test House I was fortunate in being shown the paint-testing yards where hundreds of sheets of mild steel with various paints are undergoing tests in the open. The 1934 and 1935 bitumen paint was all sooty and, except where there was red lead priming, the steel was definitely corroding.

On the other hand the 1932 red lead painting was in excellent order, though it had turned to a dull plum-grey colour.

Finally, I might mention that the engineering firm who did the painting that failed, have the contract for erecting another large steel bridge. On this, I had specified a field coat of red lead on a shop coat of same, followed by two coats of bitumastic paint with a coal tar base.

This firm have had enough of bituminous paint, and they have asked to be allowed to do two finishing coats of red oxide at less cost.

Thus, so far as the painting of highway bridges is concerned, I am now thoroughly convinced that there is nothing to compete with the best Indian made red lead and red oxide paints. Indeed I have been informed on high authority that the best Indian linseed oil is the best linseed oil in the world.

My conversion to this way of thinking has been vastly accelerated by finding two more large steel bridges in the Circle where bituminous paints are giving definitely bad service.

Indeed, it is getting this way with me now—I am positively frightened to examine any more black bridges, fearing more failures! (Laughter).

Mr. Brijmohan Lal (Punjab):—The author has done well in warning the engineers against haphazardly using the so many bituminous paints widely advertised in the market without ascertaining their composition. He has not, however, stated exactly what non-volatile materials are required in the bitumastic paints which serve as binding materials. The Irrigation Department in the Punjab have made experiments with different Bitumastic Paints for painting steel work of canal under-sluices which remain mostly under water. They have found a locally prepared mixture named the "*Khanki*" mixture to stand best in comparison with the many commercial products like Wailes Dove Bitumastic Solution, Gouresmastic black solution, Barico Grey, Anodite and Stablax paints etc. The *Khanki* mixture which has now been largely used on the steelworks of the recent canal headworks of *Panjnad*, *Khanki* and *Haveli* consists of coal tar, mineral pitch, slaked white lime or preferably cement and kerosene oil in the following proportions:—

Coal tar	...	84 lbs.
Mineral pitch	...	10 lbs.
Cement	...	9 lbs.
Kerosene oil	...	9 lbs.

The mixture is prepared by heating the pitch and coal-tar separately, then mixing them over a fire and stirring well, and adding cement gradually while stirring them, withdrawing from fire, adding kerosene oil and stirring well. The mixture should be heated to 350 degrees Fahrenheit to 450 degrees Fahrenheit; overheating burns the mixture. The covering capacity of the *Khanki* mixture is 2500 square feet to a hundred-weight and the cost of two coats of paint including hot application and all costs, but excluding the cost of preparing the surface, works out to Rs. 1/8/- per hundred square feet.

Will the author kindly state from his experience whether this mixture contains enough quantity of binding non-volatile materials to make it suitable for painting steel work in bridges? It has already proved its worth in preserving steelwork under water.

S. K. Ghose (Bihar):—Papers like the one we are discussing, which seek to analyse the causes of failures in the works of engineers, are very much more helpful than the usual descriptions of apparently successful engineering structures. It was the critical analyses of the successive failures of the famous Quebec bridge that ultimately resulted in the solution of the

problems of such big structures due to which the engineers responsible for the design and construction of the New Howrah Bridge decided in favour of a similar structure in preference to others for the city of Calcutta.

I may be permitted to point out that the average engineer cannot be a good judge of paints by superficial examination only, and it is here that the responsible opinion of such institutions as the Alipur Test House should be sought, particularly when the expenditure involved is considerable. No paints, not duly certified after thorough examination by a Test House, should be accepted for use in engineering structures. It does not take long to test the weathering qualities of a paint in the Weatherometer as was seen by the members during their visit to the Alipur Test House.

In this connection, a notable failure of the painting done on the Lower Zambezi Bridge, the second longest bridge in the world (12,064 feet) in 1935 is brought to the notice of the members on account of certain features which also obtain in a tropical country like India. The bridge was painted with three coats of "Natural Ferrador" paint, but this failed completely in 9 months' time. The cause of this failure was investigated by Dr. L. A. Jordan, Director of the Paint Research Station in England, and was found to be due to air-borne fungus spores and bacteria of a particularly virulent type. The necessity for the incorporation of a fungicide in the composition of bridge paints is clearly indicated.

The particulars of this failure can be read by interested members from the Journal of the Institution of Civil Engineers, No. 3 of 1936-37 in "Handman on the Lower Zambezi Bridge" which has been placed on the table.

Mr. Ian. A. T. Shannon (Calcutta) :—It is not my intention to advocate the use of bitumen for painting steel road bridges but there are one or two points in Mr. Murrell's paper on which I would like to comment.

The figures given in the second column on page 2 give us a certain amount of data regarding the composition of the petroleum base bituminous paint which failed, but I view with some suspicion the figure of 37.5 per cent volatile portion which is based on distilling up to 150 degrees Centigrade. I believe that most bituminous paints are made with solvents having a boiling point range somewhat higher than this, and therefore the figure of 37.5 will only represent a portion of the volatiles.

The next two figures, i.e. the percentages of solubles and insolubles in "petroleum ether" could give us the approximate bitumen content of the paint if all the solubles had been driven off. If this were the case the bitumen content would appear to be 57.7 per cent. I am, however, inclined to think that all the volatiles had not been driven off at 150 degrees Centigrade and therefore the bitumen content of the paint was probably well below this figure, say possibly 40 per cent only as against a normal bitumen content of say 75 per cent.

Assuming that this reasoning is correct it would appear that a possible explanation for the failure of this paint was that insufficient bitumen was deposited, due to the paint being applied insufficiently thickly or in an insufficient number of coats having regard to its low bitumen content.

Mr. E. Hayward (Calcutta):—I am afraid you may think my views on the subject of painting bridges are rather biased because my firm happens to manufacture Red Lead. In fact you may think I am like the Brewer who says Beer is best for everybody. However, leaving the bias aside I would like to tell you what my views are on painting bridges. For many years now, considerably more than half a century in fact, most of the biggest Engineering jobs in the world have been painted with Red Lead. Although there are cheaper paints there are also more expensive paints and if it comes to the question of economising on painting bridges it is wise to consider how an economy in paint will compare with the capital cost of the structure

Take for example a bridge like the Willingdon Bridge on the Hooghly. This cost approximately Rs. $1\frac{1}{2}$ crores and to paint it properly with Red Lead will require approximately 80 tons of Red Lead. Assuming for the sake of economy it is suggested that we give 1 coat of Red Lead with 2 coats of Bituminous paint. I calculate that there may be a saving of say Rs. 10,000/- or approximately 25 per cent of the bill for paint, there will however be no saving in the application of the paint or the cleaning of the steel. The saving of Rs. 10,000/- on a structure valued at Rs. 150 lakhs represents an economy of $1/15$ th of 1 per cent on the capital value of the bridge spread over several years.

In making this economy you are moreover running a great risk because if the paint fails, even in part, you will have very heavy structural repairs to meet.

I have studied the subject of Red Lead very carefully and my conclusion is that for outdoor structures it is better to give 2 or 3 coats of Red Lead and to be done with it for 14 or 15 years, such is my conclusion arrived at after extensive tests with Red Lead paint for protecting steel in this climate for the last twenty years.

Mr. K. E. L. Pennell (Assam):—I quite agree with the previous speaker. We have a large suspension bridge of which we are very proud.

We painted it with ANODITE antirust and IROLITE Battleship grey paints which have a bitumastic base, thinking, that as these were the paints chosen for the new Cunarder "Queen Mary" they should be good enough for our bridge.

This paint quickly started to deteriorate, a kind of chalky deposit forming which could be brushed off with one's hand.

Within two years the priming coat was exposed in many patches and the whole structure had to be repainted.

As regards new steelwork Assam is now following the British Standard Specifications i.e. "All steelwork is given one coat of boiled linseed oil at the works before despatch.

Where two surfaces will be in permanent contact after assembling, each of them is given, immediately before being assembled and after being thoroughly scraped, cleaned and dried, one coat of freshly mixed best red lead paint and the surfaces are brought together while the paint is still wet".

No painting is done until the structure has been through one rains after erection when, in the following cold weather, it is given a priming coat of non-setting red lead and a finishing coat of aluminium paint.

It is very necessary to specify a "non-setting" red lead paint for use in the field, as ordinary red lead paint deteriorates in the tin very rapidly once it is opened.

The best finishing coat paint is one with a metal base leaving a film of metal over the red lead primer. At present there are only two such paints aluminium and graphite. The aluminium paint is sold as a paste and mixed as required with a medium, it must be used within a few hours of mixing. On no account use ready mixed aluminium paint as it has probably deteriorated in the tin before it even reaches you.

Graphite is sold ready mixed. Both these paints have a very large covering capacity 1000 to 1500 square feet per gallon.

Red lead is quite useless as a finishing paint. It is much too soft and can be scratched with one's nail. It also bleaches almost white when in exposed positions and oxidises badly forming a chalky deposit.

There is however nothing to touch it for a priming or under coat.

One great advantage of aluminium as a finishing paint for bridgework is that you can see the bridge at night.

Mr. W. L. Murrell (Author):—I am much obliged to Mr. Brijmohan Lal for the prescription he has given. The details will be printed with the Proceedings, and those who care to do so may try a paint of this description.

As regards his query whether the prescription contained the necessary non-volatile plasticiser, I am afraid I do not know enough about these matters to enable me to reply.

Mr. Shannon raised the question as to whether the percentage of bitumen in the defective paint was correctly shown. In reply, I must state that I had no other estimate of the percentage of bitumen in the paint.

In reply to Mr. Ghose, I do not think that it is necessary to incorporate any fungicide in the paint. The failure described can scarcely be attributed to any "bug".

While thanking you for the kind reception you have afforded my paper, I would like to make a suggestion.

My suggestion or request to you is a very earnest one.

I would ask members of the Congress, when they go back to their jurisdictions, to look at their bituminous paint work.

If it be found that the paint is not giving reasonable service, I would suggest that the Secretary of this Roads Congress be written to accordingly.

In that case the Congress will be able to tackle the Indian Stores Department who stock so many of these bituminous paints, which are absolutely unsuited to 99 per cent of our work.

We have trusted the Indian Stores Department, and are being led astray by them !

Mr. R. A. Fitzherbert (Chairman) :—This is a paper on a subject that has not so far been discussed at the meetings of this Roads Congress, and is a most interesting one.

I have had experience of only one such case and that was in the painting of the exterior of Army Headquarters in Simla many years ago.

In this case the paint used was, as far as I remember, red oxide on red lead paint.

The failure was only in the colour, which faded badly, and this was ascribed to applying the second coat in unseasonable weather.

APPENDIX I

REPORT

OF THE

TECHNICAL SUB-COMMITTEE

TO THE

Council of the Indian Roads Congress

FOR THE YEAR 1936.

(Considered by the Council vide resolution No. 1 of its proceedings dated 23rd February, 1937 and adopted with remarks reproduced at Annex B, page 17.)

1. The Committee held one meeting during the year at which the following were present.---

Mr. K. G. Mitchell, C. I. E.

Mr. S. G. Stubbs, O. B. E.

Major W. B. Whishaw, M. C., R. E

Mr. E. F. G. Gilmore,

Mr. C. D. N. Menres, and

Mr. Jagdish Prasad, *Secretary*.

The Committee considered a letter from Major Whishaw, a copy of which is reproduced at Annex A, (page 16), and recommended as follows :—

- (a) With regard to the proposal for the grading of bitumen the Committee doubt whether it is possible to classify bitumens within rigid limits for specific purposes, but they recognise that there is at present a good deal of uncertainty in the meaning of nomenclature used in connection with bituminous materials and still some obstacle to the ready interchange of views owing to misunderstanding as to the meaning of certain words or phrases. The Committee consider that the attention of members of the Congress should again be drawn to the standard definitions, units of measurement, and so forth recommended last year and that it would be desirable for the Congress to issue a pamphlet on bituminous work which will be something between an ABC of the subject and an advanced "Code of Practice." The Committee decided to appoint a sub-committee consisting of Major Whishaw and Mr. Menres with instructions to consult Colonel Sopwith (Mr. Menres undertook to consult other bitumen interests) to draw up a simple Code of Practice on the lines indicated. This is to be published eventually as a Congress bulletin.

(b) As regards the desirability of an Information Bureau as part of the Roads Congress Organization, the Committee considered that the present is not a favourable time for suggesting increased expenditure on such things as an Information Bureau, but recommended that the attention of members should again be drawn to the fact that the Consulting Engineer (Roads) to the Government of India maintains a library, to which he adds, from time to time, when new books appear, and that as already stated he is ready to answer any questions or refer members to publications on any subjects in reply to enquiries. (Mr. Mitchell states that up to the present enquiries have been very few and he deprecated the creation of an elaborate organisation in advance of any apparent demand for it).

(c) The Committee is not prepared to recommend that the scope of the Roads Congress should be extended into a Road and Constructional Engineering or a Roads and Buildings Congress. The Committee feel that there were other Congresses and Institutions covering a wide field and that the main justification for the Congress was specialisation on road matters.

2. The Committee then considered the construction of a test-track at Alipore and the first tests to be made thereon. It was decided

- (1) that the track should be 16 feet wide;
- (2) that the mono-rail tractors being designed by Mr. Gilmore would be suitable;
- (3) that by having two tractors running one on each of the rails at opposite side of the track two sets of experiments could be carried out at the same time if necessary;
- (4) that if it were necessary or desirable to alter the direction of the test this could be done by the inter-change of the two tractors;
- (5) that the first series of experiments should be directed not only to ascertain certain definite information about certain materials but also to correlate the results of the using of the tractors at a speed (a) of 3 miles an hour which approximates to the speed of a bullock-cart and (b) 6 miles an hour. If it is found that the relative results obtained at these two different speeds are the same, it would then be possible to save much time by running the tests at the higher speed;
- (6) the track of the test trailer to be approximately 4 feet 6 inches and the tyres 2 inches wide. The slewing arrangement proposed by Mr. Gilmore which would give a lateral travel of about 18 inches to 2 feet was approved;
- (7) the soling should be of 4-inch broken brick thoroughly consolidated and upon this should be laid another

coat $4\frac{1}{2}$ -inch, loose measurement, of water-bound macadam using local stone; upon this should be laid the material to be tested;

- (8) The Committee considered that the most important test to be made first was the relative performance of different fine aggregates as chips in surface painting and that to make the test complete these should be used over water-bound macadam constructed of the same aggregate. The binder should not be varied but should be a standard hot bitumen. It was decided that four sections of the track should be laid to the full 16 feet width as follows:—

- (i) Pathankot stone with Pathankot shingle as a fine aggregate.
- (ii) Delhi stone with Delhi chips as the fine aggregate.
- (iii) Cawnpore stone with Cawnpore chips.
- (iv) Bengal granite with Bengal granite chips

- (9) The two water-bound macadam coats to be laid with a sand clay blinding or cushion laid under the loose metal. The metal should not be blinded from above.

3. (i) The Committee consider that in addition to the other records, photographic records should be kept of the condition of the water-bound macadam before the paint-coat is applied and of the surface at various stages from the commencement of the test onwards.

- (ii) It was decided to use standard bitumen as a binder in order to enable performance of the different fine aggregates to be determined with some precision. The fine aggregates to be sieved before use to approximately a uniform size and the paint-coat to be cut out at various stages, the bitumen extracted and a sieve analysis being made of the fine aggregate remaining. It was considered desirable to relate the behaviour of the fine aggregate to the results of the test of the same stone in the Deval machine in order to ascertain whether that machine gives a true picture of the property of stone for these purposes.

4. The Committee decided to hold a further meeting, if possible, in Calcutta in July or August to go into the question of further equipment at the Alipore Test House.

5. These minutes may be presented to the Council of the Congress, as the report of the sub-committee, for information and such criticism as the Council may wish to make.

ANNEX A.

Dated, the 8th January, 1937.

From

Major W. B. Whishaw, M.C., R.E.,
Engineer-in-Chief's Branch,
Army Headquarters, India,
Simla.

To

Jagdish Prasad, Esquire,
Secretary, Indian Roads Congress,
C/o The Department of Industries & Labour,
Public Works Branch,
New Delhi.

Sir,

I am afraid owing to my absence from India for a part of the year and owing to my pre-occupation since I have returned, I am out of touch with what the technical sub-committee is doing. I should be glad if you would let me know the position. In this connection I have three suggestions to make and I hope that there is still time for their consideration and incorporation in the proceedings.

Firstly—last year we defined Bitumen and I now suggest that we go into the grading of Bitumen. For this purpose, I suggest that the key to the situation lies in the penetration limits. The following penetration limits should be recognised :—

25 to 30	50 to 60	85 to 100
30 to 40	60 to 70	100 to 120
40 to 50	70 to 85	120 to 150
	150 to 200	

(In this connection see Highway Engineering by Bateman—page 249).

I further suggest that in regard to India, the following penetrations are suitable :—

For Road Bitumen applied hot

Surface dressing	.. .. .	60 to 100
Grouting	.. .. .	30 to 50
Premix	.. .. .	25 to 40

I suggest that within each group, the harder ranges should be used with harder stones and softer ranges with softer stones.

The only use to which Road Bitumen within the group, 100 to 200 is put in India is in the manufacture of road emulsion.

The types of Bitumen used in Cut-Backs in India is less definite. All that can be said at present is that Bitumen in Cut-Backs are generally softer than Bitumen applied hot and that in no case is Bitumen harder than 40 used in Cut-Backs.

Secondly—as regards the Congress Library; the present arrangements of being able to use the Library of the Consulting Engineer to the Government of India, Roads, is recognised, I believe, as a temporary expedient only. I suggest that what the Congress needs is not only a Library, but an Information Bureau with a proper system of indexing information in the manner that is done by the Central Board of Irrigation who also issue a quarterly Bulletin indicating what new material has come to hand. As I do not presume that this work of indexing could be undertaken by the office of the Consulting Engineer to the Government of India, Roads, I suggest that the Central Board of Irrigation be approached as to the terms and conditions under which they would be prepared to undertake the stocking of books on road matters and indexing

of the information therein on behalf of the Indian Roads Congress. I understand that from the point of view of the Indian Roads Congress, it is probable that the cost would be negligible, (after the order of Rs. 1,500/- per annum), in comparison with the benefits. I further suggest that such a combination or amalgamation of engineering effort would have the further advantage of creating a step towards the eventual establishment of a Central Scientific Library meeting the demands of all engineers in India.

Thirdly—I am of the opinion that the material for an Annual Congress on Roads, pure and simple, will not in the near future produce enough new material. Admittedly we are taking up the question of Bridging which is limitless subject. At the same time Bridging is so inter-connected with Structural Engineering generally that it would be a pity, if eventually Bridging becomes the main justification for the Roads Congress, to exclude general Structural Engineering from the Agenda. I, therefore, suggest that at least the feeling of the Congress at Lucknow should be gauged as to their views in respect to making this a Road, Bridge and Structural Engineering or, if you like a Roads and Buildings Congress.

I have the honour to be,

Sir,

Your most obedient servant,

W. B. WHISHAW,

Majorc, R.E.

ANNEX B.

The Council considered and adopted the report of the Technical Sub-Committee subject to the following comments and instructions :—

(1) With reference to sub-paragraph (c) of paragraph 1 it was suggested that the Technical Sub-Committee had not opposed the extension of the activities of the Roads Congress for all time, but merely held that the present moment was not opportune. This view was accepted.

(2) In connexion with the Sub-Committee's recommendations for the test to be carried out on the test track, which were accepted, the Sub-Committee was instructed to consider what research, whether on a test track or otherwise, is possible in connexion with the effect upon water-bound macadam of mechanical transport and particularly the feature of corrugation.

(3) Mr. Radice then introduced his proposal that the commencement of standardisation through the Bridge Committee should be followed up by the creation of a standing standards committee. He explained the object of his proposal, and a few questions were put by certain members. Mr. Mitchell suggested that what Mr. Radice wanted was that the Government of India should not only be asked to continue the existing subsidy but be informed that the Congress might propose considerably increased expenditure on Research requiring larger subsidies. It was decided that the proposal should be discussed in the business session of Congress and that the Congress might be asked to authorise the Council to go into the question and see how it should be pursued, and whether the attention of the Government of India should be drawn to it at the time they are asked to continue the existing financial arrangement.

APPENDIX II

REPORT
OF THE
TECHNICAL SUB-COMMITTEE
TO THE
Council of the Indian Roads Congress
FOR THE YEAR 1937.

(Considered and approved by the Council vide its resolution No. 10, dated the 31st December 1937).

The Technical Sub-Committee held its first meeting at Simla on the 25th May, 1937. The minutes of this meeting (reproduced at Annex C, page 18) were duly circulated to the Council.

The second meeting of the Sub-Committee was held at Hyderabad on the 31st December, 1937. The minutes of this meeting are attached (Annex D, page 34). Two of the original members, Mr. K. G. Mitchell and Major W. B. Whishaw having proceeded on leave, their place was filled by Messrs. L. B. Gilbert and Mr. Trevor-Jones.

The Committee would reiterate their view already expressed in the minutes of their first meeting that Mr. Murrell's suggestion to use a primer (crude tar, etc), with sand as first coat followed by a second coat of stone chips bound in some bituminous material should give excellent results and should be given fair trial. They propose to test this at the test track at Alipore at an early opportunity.

The Committee have, on the suggestion of Colonel Sopwith decided to carry out tests regarding the performance of chips in surface dressing using tar as the binder over a length of 100 feet in the middle of each straight length of the Test Track.

ANNEX C.

Minutes of the Proceedings of the Technical Sub-Committee of the Indian Roads Congress held at Simla on the 25th May, 1937.

PRESENT.

Mr. S. G. Stubbs, O.B.E.	President of the Congress (in the chair).
Mr. K. G. Mitchell, C.I.E.	
Mr. E. F. G. Gilmore	
Major W. B. Whishaw, O.B.E., M.C., R.E.	
Mr. C. D. N. Meares	
Mr. Jagdish Prasad (Secretary).	

The committee considered the draft specifications for the Test Track to be established at Alipore and after some discussion adopted the specification as at Appendix I, page 20. The committee were of opinion that after the first test on the relative performance of chips in surface painting is over, tests should be made to explore the possibilities of road surface composed of a primer coat of thin tar (or cut-back) and sand and a second coat of pre-mixed stone chips. The committee examined and approved the detailed drawings of the test track, tractor and trailer prepared by Mr. E. F. G. Gilmore and expressed their thanks to him for the trouble he had taken.

2. The Committee considered Mr. Murrell's letter (vide Appendix 2, page 23) and came to the following conclusions :—

(a) Regarding Mr. Murrell's suggestion that tests be carried out at Alipore to determine the reasons for corrugation of water-bound macadam in order to devise a specification for a non-corrugating surface, the Committee decided that they could not see their way to make these tests at Alipore. In the first place the test track is designed for tests at slow speed and with the express object of determining the effect of bullock-carts upon different kinds of surfacing materials. A track to reproduce the conditions of corrugation would obviously have to be run at speeds comparable with those of motor vehicles on the road and having regard to the axle weight which would be necessary the track would have to be circular on the lines of the new heavy test track at Harmondsworth and would be extremely expensive. It is doubtful moreover whether such a track would give reliable results, because the effect of a vehicle moving on a relatively small radius is probably greatly different to that of one moving on a straight line and the contributory effect of the prevailing direction of the wind, if any, would be lost. The Committee considered that observations in respect of corrugation could be made on any road subject to heavy motor vehicle traffic provided a by-pass road were made to take all other kinds of traffic. Arrangements could then be made for ordinary motor traffic, or certain classes of it, which could be counted, to run over the test road first in one direction, then in another, and finally in both directions. The members of the Committee were not prepared to express any definite opinion as to the probable causes of corrugation but considered that one or both of the following were contributory causes :—

- (i) Wheel spin throwing up loose surface blindage, and
- (ii) defective rolling of thick coats of metal which produce the effect of the metal creeping in front of the roller and then forming a hard ridge over which the roller rides to commence another depression.

The Committee decided to inform Mr. Murrell that, if he could see his way to arrange and supervise a test of the nature suggested, they would be prepared to make a recommendation that the necessary money should be provided by the Government of India. At the same time Mr. Murrell should be informed that the Committee appreciated the importance of the subject and regretted that they could not undertake to investigate it at Alipore.

(b) As regards Mr. Murrell's suggestion regarding the use of a primer with sand as a first step in surface treatment to be followed by a second coat of stone chips bound with some bituminous material, the Committee thought that this form of treatment would probably give excellent results and decide to make a test of it on the test track at an early opportunity.

3. The committee next considered the letter of Messrs. Imperial Chemical Industries India, Limited (vide Appendix 3, page 24), and resolved that the Provinces may be asked to try calcium chloride for stabilizing both water-bound and earth roads in tracts where humidity was low provided a free supply of the chemical was made by the manufacturers. The committee did not consider it necessary to give calcium chloride a trial on the test track as the material was thought to be only of local interest.

4. Regarding Mr. Radice's proposal for the creation of a central authority for standardisation, organisation, etc. (vide Appendix 4, page 31) the committee were of opinion that what was necessary at the present stage could be achieved with the co-operation of members of "Code of Practice" sub-committee, the technical sub-committee and the council of the Indian Roads Congress.

5. Regarding paragraph 1 (2) of the minutes of the second meeting of the council held at Lucknow on February 23, 1937 (*vide* Appendix 5, page 34) the committee's opinion was stated in paragraph 2 above.

6. The committee considered Col. Smith's suggestion regarding the feasibility of keeping prominently before the Congress, in the form of a paper, the question of widening traffic lanes and decided after some discussion that the object would be achieved if Major Whishaw and Mr. Meares who were writing a general code of practice for road work, could bring it, in the form of a paper, for discussion before the Congress. After the Congress had expressed its views on the paper, it would be published separately as a Congress publication.

7. Regarding the distance at which road signs should be fixed from the point of danger, the committee was of opinion that the normal distance should be a furlong, the minimum distance being 400 feet. They desired that the various automobile associations should be consulted in the matter.

APPENDIX 1 TO ANNEX C.

ALIPORE TEST TRACK SPECIFICATION.

(1) The track shall consist of two straight sides 150 feet long joined at each end by semicircles of 50 feet radius. The width of the track shall be 16 feet and it will be divided into four sections each containing half the length of a straight side and half of one of the end curves.

(2) The mono-rail tractors with cantilever draw-bar being designed by Mr. Gilmore will each command half the track width from opposite rails.

(3) If necessary, two sets of experiments will be carried out at the same time, by running one tractor on each of the rails at opposite side of the track.

(4) It may be desirable to alter the direction of the test and Mr. Gilmore will consider whether this could be done by the inter-change of the two tractors.

(5) The first series of experiments will be directed not only to obtaining information about certain materials but also to correlate the results of using the tractors at a speed (a) of 3 miles an hour, which approximates to the speed of a bullock-cart and (b) 6 miles an hour. If it is found that the relative results obtained at these two different speeds are the same, it would then be possible to save much time by running the tests at the higher speed.

(6) The track of the test trailer to be approximately 4 feet 6 inches, the wheels 3 feet 6 inches in diameter and the tyres 2 inches wide. The slewing arrangement proposed by Mr. Gilmore will give a lateral travel of about 18 inches to 2 feet. Probably a worn track of 8 inches for each wheel will suffice. The transverse motion of the slewing arm should, if possible, be quick-reverse rather than harmonic to prevent convex wear. The usual wear on roads is concave.

(7) The soling shall be six inches thick composed of broken brick 2-inch to 4-inch gauge thoroughly consolidated and upon this shall be laid another coat $4\frac{1}{2}$ -inch, loose measurement, of water-bound macadam using local stone; upon this shall be laid the material to be tested; (*vide* appendix 1 A, page 22, for detailed specification for consolidation).

(8) The first test will be made to determine the relative performance of different fine aggregates as chips in surface painting used over a coat of water-bound macadam $4\frac{1}{2}$ -inch loose measurement, constructed of the same aggregate as the chips in each case. The binder shall not be varied but shall be a standard hot bitumen 80-100 penetration sprayed at the rate of 45 pounds per 100 square feet. The four sections of the track shall be laid to the full 16 feet width using :—

(i) Pathankot stone with Pathankot shingle as a fine aggregate.

(ii) Delhi stone with Delhi chips as the fine aggregate.

- (iii) Jhansi stone with Jhansi chips.
- (iv) Bengal granite with Bengal granite chips.

(9) The two water-bound macadam coats, viz. the first coat of local stone and the test coat of imported stone, shall be laid with about one inch of clay blinding and cushion laid under the loose metal, to be worked up into the interstices by rolling. The metal should not be blinded from above, nor should gritty material be used.

(10) The following records will be maintained:—

- (a) Range of temperature during laying and every day during the actual test, the maximum and minimum readings of wet and dry bulb thermometer being observed.
- (b) Dates of commencement and completion of each experiment.
- (c) Daily rainfall during the period of test.
- (d) Quantities and costs of the various materials used in the test track.
- (e) Description of plant used, the weight of rollers and dimensions of rollers, and the number of times rolling is done over the chips in the paint coat.
- (f) Daily record of the condition of surfaces under test and the nature of damage that occurs.
- (g) Photographic records of the condition of the water-bound macadam before the paint coat is applied and of the surface at various stages from the commencement of the test onwards. These photos to be dated by the inclusion in the photo of a black-board with the date in white chalk.
- (h) Records of routine tests on bitumen used, e.g. penetration, melting point and ductility.

(11) The fine aggregate will be $\frac{1}{2}$ -inch gauge, i.e., passing through a square mesh of $\frac{3}{4}$ inch and retained on a square mesh of $\frac{3}{8}$ inch and shall be evenly spread at the rate of 5 cubic feet per hundred square feet of surface.

When the road surface is bone dry, it will be thoroughly cleaned and bitumen will be applied hot at the temperature specified by the manufacturers and shall be evenly sprayed or poured from pouring cans as the suppliers shall specify. Gritting will be done uniformly immediately after pouring bitumen, and will be followed by rolling with a 4-ton roller till the chips have set. The number of times the roller is passed over will be recorded.

(12) The fine aggregates will be carefully sieved before use to the size specified. The paint coat will be cut out at various stages, the bitumen being extracted and a sieve analysis being made of the fine aggregate remaining. The behaviour of the fine aggregate will be compared with the results of the test of the same stone in the Deval machine in order to ascertain whether that machine gives a true picture of the property of stone for these purposes. When the surface of the water-bound macadam under the paint coat is exposed for about 25 per cent of the area of the worn tracks, the paint coat will be deemed to have failed. The nature of the failure, i.e., by wear or peeling will be carefully observed and recorded and the paint coat will be stripped and if the underlying macadam is in good order a further coat will be laid for test.

(13) A line will be marked along the centre line of the track and be divided into five-foot lengths starting from the centre of one straight side. These 5' lengths will be permanently painted and numbered on some fixed rail or otherwise outside the side guide rails by lines drawn normal to the centre line. The units on the outside of the end curves will thus be greater and on the inside less than 5'. All records of the behaviour of the material will be described by the five-foot sections thus demarcated. These sections will be reproduced on a large scale plan and numbered.

(14) Local failure in the paint coat due to minor local defects will be repaired with identical material and the repairs carried out will be carefully recorded.

The records should show the quantities of bitumen and chips used and the area patched in each section on any particular date. The position of patches should be marked on the large scale plan and the date on which the first patch is formed should be noted.

(15) The wheels of the test tractor are to be loaded in the first instance to 1000 pounds per inch width of tyre *i.e.*, for two-wheeled test-tractor with two-inch tyres the total weight of each tractor will be 4000 pounds.

APPENDIX I A TO ANNEX C.

CONSOLIDATION OF SOLING.

(a) Over-burnt hard bricks broken to ballast of 2-inch to 4-inch gauge will be used for soling.

(b) The trench* to receive the soling will have vertical sides and the profile of the base will have a camber of 1 in 60. The trench will be lightly watered and rolled before laying the soling.

(c) The ballast will be carefully hand-packed to reduce the interstices to a minimum. The depth of the packed ballast will be 6 inches and the surface profile will have a camber of 1 in 60.

(d) The surface will be rolled with 12-ton steam, road roller, at first dry, and then after sprinkling water, till the ballast has firmly set. Any settlement which occurs on rolling should be made good by additional ballast.

CONSOLIDATION OF INTERMEDIATE COAT.

(a) The metal for this coat will be Bengal granite obtained from approved quarry and broken to 2 inch gauge, *i.e.*, it shall pass a square mesh of $2\frac{1}{2}$ inches and shall be retained on a square mesh of $1\frac{1}{2}$ inches. The metal shall be free from dust or extraneous matter.

(b) The surface of the soling will be cleaned and a layer of good dry clay will be evenly spread to a thickness of 1 inch over which the metal will be evenly spread and carefully hand-packed to a depth of $4\frac{1}{2}$ inches and to a camber of 1 in 60. The camber will be checked while spreading metal by means of templates placed at close intervals. The metal shall then be rolled with a 12-ton road roller, commencing at the edges and working towards the centre.

Dry rolling will be continued till there is no appreciable movement in the metal under the roller or when walked upon.

The metal will then be sparingly watered and the rolling continued till the metal becomes compact and the clay works up from underneath. Rolling will be stopped when no marks of the roller wheel are noticeable on the surface.

(c) The surface shall be kept watered for a week after consolidation in case the top coat is not to be consolidated immediately after the intermediate coat.

CONSOLIDATION OF TOP COAT.

The metal for the top coat will be obtained from the localities specified in the main specification.

* The trench will be 16 feet wide and 12 inches deep to receive the soling and two coats of metal.

The size of the broken metal shall conform to the following grading :—

75 per cent — $1\frac{1}{2}$ inch gauge (passing a square mesh of 2 inches and retained on a square mesh of 1 inch).

25 per cent — $\frac{1}{4}$ inch gauge (passing a square mesh of 1 inch and retained on a square mesh of $\frac{1}{2}$ inch).

The two grades will be mixed together before laying. Laying and consolidation will be done in the manner indicated for the intermediate coat.

APPENDIX 2 TO ANNEX C.

Copy of letter No. 2941, dated the 2nd April 1937, from the Officiating Superintending Engineer, Chota Nagpur Circle, Ranchi, to the Secretary, Indian Roads Congress.

Subject :—3rd Indian Roads Congress at Lucknow. Report of the Technical Sub-Committee of the Indian Roads Congress for 1936.

Reference :—Nil.

I have the honour to state that, in the absence of the Chief Engineer at Lucknow I was called on to represent Bihar on the Congress Council, and accordingly did so.

When proposal 8 (Test Track) of the Committee was under discussion in Council I urged the necessity of the following two points :—

- (a) Test wheels to represent motor transport to carry a ratio of sprung to unsprung load and to be driven from the hub and not merely dragged.
- (b) Experiments should be done on water-bound macadam consolidated according to different specifications, as soon as possible.

I went as far as requesting that my suggestion (b) be recorded, and gave as my reason that the Province of Bihar has not a great deal to spend on communications. This lack of funds meant the curtailment of surface sealing, and the maintenance of a high percentage of water-bound macadam surface which was very subject to corrugation. To put it briefly, Bihar is more interested in obtaining the best specification for a non-corrugating water-bound macadam road than it is in the behaviour of different kinds of grits used in the sealing of water-bound surfaces.

So far as I know, my suggestion, not to say protest, on behalf of Bihar, has not been recorded.

Another reason for this present communication is a conviction, formed since the Lucknow Congress, that the specification for laying the test sections is not one from which the most useful results will be obtained.

While admitting that it is necessary, for the sake of simplicity, not to vary the binder I now suggest that the method of its application should at least approximate to the usual method in which a binder is used in Indian sealing work, or to a method in which it could be economically used in sealing work in India.

In reality in India, we invariably blind our water-bound macadam before we seal it. The method proposed by the Sub-Committee, i.e., the application of hot binder to newly rolled but unblinded water-bound macadam i.e., a semi-grout, is certainly not general practice in India.

I know of no country where it is general practice, and the reason is doubtless that given in pages 387 and 393 of Bulletin No. 108 of the Permanent International Association of Road Congress for November-December 1936.

If any weight is attached to this suggestion to approximate the Test Track methods to practical Indian methods, it is obvious that the Sub-Committee who will discuss the Test Track in Calcutta in July should consult also the Sub-Committee consisting of Major Whishaw and Mr. Mearns who, in consultation with Colonel Sopwith, are to draw up a Code of Practice for Indian seal coat work.

Reference to this proposed Code again causes me to write on matters which affect Bihar, and this time the issue is the incorporation in the specification of the uses of tar, and by "tar" I mean crude tar as well as No. 1 and No. 2 Road Tar, the products, more or less directly, of Bihar and Bengal coal.

The following is an outline of my experience gained in portion of Bihar, and it is proffered in the hope that it will be useful.

Except for experiments done with chips and distilled tar and bitumen in 1929 and 1930, most sealing to water-bound surfaces up to about 1931 or 1932 was done with heated crude tar, sometimes mixed with pitch, and blinded with coarse sand, the seal being repeated annually.

From about 1932 to 1935, crude tar gradually became replaced by distilled tars viz. Road Tar Nos. 1 and 2 and a little bitumen; but coarse sand was still the blinder. This seal was done every 2 or 3 years on the less important roads, and every year or two on the more important roads.

Late in 1935 and 1936, fairly large quantities of straight bitumen of penetration about 100, and No. 2 Road Tar were laid down, and chips were used to the total exclusion of sand as a blinder.

Where this work was done on newly consolidated water-bound macadam, it was very expensive owing to the necessity of cleaning the water-bound surface sufficiently to get a good key, which resulted in high consumption of binder 45 to 55 pounds per 100/- square feet. Proper boilers, bass brooms and rubber squeegees were used.

Owing to this high cost and a lot of inefficient work in spreading the binder, I adopted a specification which I had seen used in Australia and which consist of stone chips bound with bitumen or distilled tar as a second coat, done soon after a primer coat of thin tar and sand, which had followed soon after reconsolidation of the water-bound macadam.

The "thin tar" used here in the primer seal is sometimes good crude tar and sometimes No. 1 tar.

A point about the crude tar is that it "takes" better to the damp surface than does the thin distilled tar.

In this connection it is well to remember that, at the Lucknow Congress, a number of speakers stressed the necessity of sealing the new water-bound surface, as soon as possible. Bitumen and the more viscous distilled tars do not take so well to the damp surface as good crude tar, which itself contains a fair amount of water.

This two-coat method is now proving more successful than the single heavy coat method owing partly to the greater ease in spreading the binders and partly to the less consumption of the more expensive binder, whether tar or bitumen.

Another reason, why I should like to bring this local experience to the notice of the Code Sub-Committee, is the complete substantiation which the system obtains from an important paper "The selection of binders for superficial treatment," just published in Bulletin No. 108 of the Permanent International Association of Road Congresses for November-December 1936.

Should the Code Sub-Committee be interested, I would be glad to reply to any queries.

They may also be interested in a certain amount of success in our efforts to cheapen the cost of chips for blinding by employing a small portable granulator driven by a Diesel road roller.

APPENDIX 3 TO ANNEX C.

Copy of letter dated Calcutta, 20th March, 1937, from the Director, Imperial Chemical Industries (India) Ltd. to the Consulting Engineer (Roads), P. W. D. Branch, Department of Industries and Labour, New Delhi.

Subject :— Calcium Chloride—Its use in the construction of Stabilised Roads.

We learn that very shortly a Government Test Track is to be built in Alipore, for testing the relative merits of various road-making materials and of different methods of road construction.

We would like to bring to your notice a comparatively new method of building water-bound roads which has already won much favour in countries where there are still large milages of this type of road, notably in the U.S.A. and Canada, and in Sweden and Norway.

The secret of this new technique of 'stabilised' road construction is Calcium Chloride, a highly hygroscopic substance. By absorbing moisture from the atmosphere it ensures that the moisture content of the road surface is maintained at the right degree so that maximum consolidation is obtained.

We enclose a copy of our report Tr/181 which contains, in brief, most of the available information on the subject. It will be noticed that the suitability of stabilised roads for any particular locality depends on the prevailing atmospheric conditions. From meteorological data available, it looks as if conditions are suitable throughout the year in coastal districts, and that they are unsuitable for one or two months during the year in the Punjab and Rajputana and possibly in some parts of the United Provinces and Central Provinces.

The report also outlines briefly the methods of construction and maintenance. The exact proportion of gravel to clay, in the road material to be used in each locality, is probably a matter to be decided upon after preliminary experiments.

Trials with Calcium Chloride are now being carried out in Mysore by a European firm of constructional engineers and we have had several requests for information about stabilised roads from other parts of India.

We very much hope that a trial of road surfaces stabilised with Calcium Chloride can be made on the new Test Track since we feel that this method of road construction may be of considerable value in India where the great need is for hard-wearing roads whose construction and upkeep do not involve heavy expenditure.

If you are willing to lay down a short stretch of stabilised road for experimental purposes, we shall be happy to supply the necessary Calcium Chloride free of charge.

IMPERIAL CHEMICAL INDUSTRIES (India) Ltd.

Technical Report No. TR/181.

CALCIUM CHLORIDE : ITS USE IN STABILISED ROAD MAKING.

I. SUMMARY.

In countries like the U.S.A. and Canada, which possess large milages of water-bound roads, increasing quantities of calcium chloride are being used, both for laying dust and in the new technique of stabilised road construction.

An examination of the properties of calcium chloride in relation to climate shows, that in Australia and New Zealand, South Africa and certain parts of India and South America, conditions are favourable for the use of calcium chloride both as dust palliative and in road stabilisation.

The development, underlying principles and method of construction of stabilised roads are discussed, and reference is made to their durability and cost.

It is stated that calcium chloride has no deleterious effect on the hooves of animals, the tyres of automobiles or other materials likely to pass over roads treated with it.

II. INTRODUCTION.

In the last four or five years growing attention has been directed to the use of calcium chloride in road maintenance. In the U.S.A., Canada, and Sweden especially, highway engineers have made much use of this salt as a dust palliative and in building of stabilised roads. The latter is a new type of highway, which is being rapidly developed in the U.S.A. and there seems no reason why it should not prove practical in other large countries, such as Australia, where it is difficult, owing to cost, to construct first-class tar-bound macadam roads anywhere but in the neighbourhood of large centres of population.

This report collects existing knowledge about the use of calcium chloride on roads, and indicates certain factors principally climate, which govern the potential use of the product in India.

III. THE PROPERTIES OF CALCIUM CHLORIDE WITH REFERENCE TO THEIR APPLICATION IN HIGHWAY MAINTENANCE.

Calcium chloride is extremely soluble in water and very hygroscopic. It is on these two properties that its use in road maintenance depends; for its hygroscopic nature enables it to bind dust, and to maintain the gravel-clay mixture of a stabilised road at the optimum degree of moistness for maximum consolidation.

By far the most importance attaches to its hygroscopic properties. Two opposing forces are at work:—

- (1) The tendency of water vapour in the air to condense on and dissolve the calcium chloride.
- (2) The tendency of the solution of calcium chloride to evaporate, giving up its water to the atmosphere.

For successful dust laying, it is necessary that (1) shall be greater than (2), or, more concisely, that the partial pressure of aqueous vapour in the air shall be greater than the tension of aqueous vapour of a saturated solution of calcium chloride at the same temperature.

Since evaporation is not an instantaneous process, it follows that calcium chloride may still be successfully used in some of the localities where (1) is less than (2) for very short periods of the day, the moisture absorbed during the hours when (1) is greater than (2), serving to tide over the interval during which (1) is less than (2).

It should also be realised that the temperature of a road surface, exposed to the full glare of the sun, may be several degrees higher than that of the surrounding atmosphere, so that evaporation may proceed further than might be expected from air temperatures and humidities. On the other hand, the layer of air, immediately in contact with the surface, might be expected to be at about the same temperature as the surface, and in the absence of strong winds it is this layer which has the largest influence on the rate of evaporation of the surface.

A further point to be borne in mind when considering any given locality is the daily variation in temperature. Meteorological data for a district consist as a rule of "mean temperatures", and "mean humidities", so that when assessing the value of calcium chloride as a dust layer, allowance should be made for some variation—say 10 centigrade degrees—on each side of the mean temperature.

Below in a table of temperatures, and limiting humidities below which calcium chloride is useless:—

Temperature		Humidity below which calcium chloride is useless.
5	.. ..	40.0
10	.. ..	37.5
15	.. ..	34.7
20	.. ..	32.0
25	.. ..	28.0
30	.. ..	21.0
35	.. ..	20.5
40	.. ..	18.6
50	.. ..	17.0

IV. PUBLISHED DATA CONCERNING THE CONSUMPTION OF CALCIUM CHLORIDE IN ROAD MAINTENANCE.

Although calcium chloride is no longer used for dust laying on roads in Britain, owing to the adoption of tar-bound or concrete roads, which are dustless, the position is different in other countries where there still are large milages of water-bound roads, notably in the U.S.A. and Canada, and in Sweden and Norway.

The adoption of stabilised roads is causing an increase in the consumption of calcium chloride in these countries, an increase mainly due to the large amount of pioneer work carried out by the Dow Chemical Company and the U.S. Highway Research Board. Most of the information about stabilised roads, especially on the theoretical side, comes from the work of the Road Stabilisation Department of the Dow Chemical Company.

The annual consumption of calcium chloride for road maintenance in the years 1931-33 was in the U.S.A. between 70,000 and 100,000 tons, in Canada about 20,000 and large quantities in Sweden and Norway.

Mr. B. C. Tiney of the Michigan State Highway Department is quoted as saying:— "Michigan's large milage of gravel roads present a serious problem in elimination or reduction of dust. Our programme this year (1935) includes the treating of approximately 3,650 miles of gravel roads, using 30,500 tons of calcium chloride".

To understand the reason for the large U.S.A. consumption, it must be realised that there are in that country only small milages of first-class roads in relation to its size. Thus with an area more than thirty times that of Great Britain it possesses only about three quarters of Britain's milage of first-class tar-bound or concrete roads. There are in the U.S.A. some 2,000,000 miles of roads with no surface other than the soil of the district and some 500,000 miles of water-bound gravel roads. These facts, taken in conjunction with the very large number of automobiles, (25,000,000 or one to every 5 persons), make the case of the U.S.A. a special one, and not one from which it is safe to deduce estimates of potential consumption of calcium chloride in countries, where its use is as yet undeveloped.

Apart from the U.S.A., Canada, Sweden and Norway there are as yet no other countries in which calcium chloride is used to any appreciable extent for highway maintenance.

V. THE BEARING OF CLIMATE ON THE USE OF CALCIUM CHLORIDE.

India.

The average temperature reduced to sea level is about 75 deg. F. over the whole of India, except parts of the extreme north, and exceeds 80 deg. F. over all peninsular India, except the west coast and all the more southerly parts of Burma.

The humidity is moderate, but less than 50 per cent in Rajputana, whereas in coastal districts in the east it is so high as 80 per cent.

It is not possible to make more than a rough estimate of the magnitude of the areas over which calcium chloride would be effective. From information collected it would appear that most coastal districts are amenable to treatment, but Rajputana, the Central Provinces, and the Punjab are not suitable. Over roughly one-third of the country calcium chloride should be useful.

Judging from meteorological data, therefore, it would seem feasible to build stabilised roads in parts of India. Moreover, the country is precisely of that type for which such roads are an economic proposition, because it is one in which the immense distances involved make it financially difficult to construct first grade tar-bound roads anywhere except around large towns.

It is beyond the scope of this report to estimate the market for calcium chloride in road maintenance, except in so far as to point out that so small a length as 100 miles of stabilised road 20 feet wide would absorb not less than 1,000 tons of calcium chloride, (600 of which are required for annual maintenance)—and there are in Australia alone more than 50,000 miles of water-bound roads at present unstabilised.

VI. THE USE OF CALCIUM CHLORIDE FOR STABILISED ROADS.

(a) Investigations in the U.S.A.

The United States with 25,000,000 automobiles, or on an average one to every five persons, is in a peculiar position with regard to roads. For although the area of the country is more than thirty times that of Great Britain (including N. Ireland) there are only about 100,000 miles of first class tar-bound or concrete roads compared with some 176,000 in Great Britain, and yet there are only about 2,000,000 automobiles in Great Britain, or roughly one for every 20 persons.

Thus there is a great need for many more miles of roads in the U.S.A. fit for motor traffic, but as the cost of construction in tar-bound macadam would be prohibitive, some method had to be devised whereby a cheap durable road could be built. The solution to this problem has been found in the stabilised road, and thanks to valuable experimental work by the Dow Chemical Company, and the U.S.A. Highways Research Board, and large-scale trials by the State of Michigan, a satisfactory technique has now been worked out, and the stabilised road is being developed rapidly, not only in the U.S.A. but also in Canada and Sweden.

The stabilised road is cheap to construct and cheap to maintain, the cost being on an average about $1/20$ of that of a first-class tar-bound or concrete road.

(b) Underlying Principles of Road Stabilisation.

Sand or gravel when dry has no cohesive properties, and clay when moist, has no strength although sticky. On the other hand, moist sand or gravel is coherent, and dry clay hard and strong. If, therefore, a suitable gravel-clay mixture be chosen, it should be possible to use it as a durable road material so long as its moisture content is maintained at the optimum level for maximum strength and coherence.

Calcium chloride is the agent, by means of which it is possible to maintain the correct moisture level. The broad principle underlying the construction of a stabilised road is to mix gravel with the existing road material if the latter be too clayey, or to mix clay with it if too gravelly, and in either case to incorporate calcium chloride in the mixture.

The mixing must not be haphazard, and very careful preliminary analysis of the soil of the district are necessary to enable the highway engineers to determine how much gravel and clay are required to bring the gravel-clay ratio to the most suitable value for the district.

As ideally stabilised wearing course may be described as one that will give proper support to wheel loads, will not become slippery and rutty in wet weather, and will not ravel or become dusty in dry weather. Such a wearing course is composed of a mixture of coarse aggregate, fine aggregate, silt, clay and calcium chloride in

proper proportions, and in quantities that will provide all-weather stability. The aggregate should be embedded in the soil-mortar, leaving the surface smooth with a mosaic appearance and practically free from floating material.

The functions of the various components of the road surface are :—

(i) *Coarse Aggregate* :—Screen size to be coarser than No. 10 sieve, (U.S. Standard series). Stone larger than $\frac{3}{4}$ inch should be ranked out of the top surface to facilitate blading. The ingredient contributes rigidity and high internal friction, and adds to the mechanical stability of the road surface.

(ii) *Coarse Sand*, screen size-through No. 10 over No. 40 sieve. Serves the same purpose as coarse aggregate. Helps to lock the coarse aggregate to place.

(iii) *Fine Sand*, screen size-through No. 40—over No. 270 sieve. Fills voids in coarse sand. Non-expansive ingredient.

(iv) *Silt*, has high capillary properties. Serves as a reservoir for calcium chloride, contributes but little to rigidity of road surface. Fills voids in fine sand. Expands when moistened. Has no cohesive properties or toughness.

(v) *Clay*, supplies cohesion or toughness. Has expansive properties. Fills voids completely making road surface impermeable. Serves as a reservoir for calcium chloride.

(vi) *Calcium Chloride*, tends to maintain the moisture in the road surface at an optimum content which maintains the toughness of the road. It is driven into the road surface by rains, reappears at the surface by capillarity in dry weather. Reduces evaporation and attracts moisture from the atmosphere.

(c) Methods of Construction of Stabilised Roads.

It is not proposed in this report to go in detail into the methods of construction. What follows, is condensed from various sources of information, which are listed at the end of the report.

The first step is, by analysis, to determine the amounts of sand and gravel and clay to be added to the sub-grade soil, or to the existing road surface.

Work is commenced on half-mile sections at a time and after scarifying the surface, all loose material is windrowed so that it forms a pile 8 to 12 feet wide down the centre of the roadway. The new material required, (except the clay), is then spread on top of the pile so as to bring the total quantity up to about 1,000 cubic yards per mile. This quantity when stabilised will produce a wearing course 3 inches deep and 20 feet wide. The stabilised layers should never be less than 3 inches in depth.

The calculated amount of clay is then spread uniformly over the surface of the loose material, and as it dries it is pulverised by manipulation and rolling. When the pulverising operation has been completed the materials are mixed in the usual way by blading and harrowing.

Flake calcium chloride is then applied uniformly at the rate of $\frac{1}{2}$ pound per square yard per inch of thickness with a maximum of 2 pounds per square yard.

The mass is thoroughly mixed by blading, and after mixing is windrowed again on to each shoulder of the road. The central portion of the road is now uniformly moistened with water and some of the material from the shoulders bladed on to it. This is in turn moistened and covered, and so on, until all the material on the shoulders has been distributed and a crown of not less than $\frac{1}{4}$ inch per foot established.

Traffic is allowed over the bladed material all this time (i.e., after the calcium chloride has been mixed in) and when all the material has been placed, the surface is smoothed and traffic allowed to continue the consolidation process for 24 to 48 hours, after which it should be complete.

Some authorities delay the addition of calcium chloride until the road surface is completely established. The flakes are then spread over the surface and left to absorb moisture and soak into the road metal. In general, however, it has been found more satisfactory to incorporate the calcium chloride in the mix, as described above, rather than to depend on percolation to carry the salt into the wearing course.

(d) Quantities of Calcium Chloride Required.

As described above, the quantity of calcium chloride to be used is of the order of $\frac{1}{2}$ lb. per square yard per inch of thickness with a maximum of 2 pounds per square yard. This amounts to about 10 tons per mile of road 20 feet wide. If the road is constructed in late summer or autumn this quantity may advantageously be reduced to about 8 or 6 tons per mile.

(d) Quantities of Calcium Chloride Required.

Whenever the roadway loses its crown and smoothness, it should be re-shaped by blading from the edges inwards, in a manner that will gather the loose material from the shoulders, cut off the high places and fill in the low.

Flake calcium chloride should be added as required to maintain the correct moisture level. Under normal climatic conditions and normal country-road traffic the quantity required varies from one to two pounds per square yard per annum, *i.e.*, from 5 to 10 tons per mile of 20 feet width.

As a rule, blading is necessary only a few times each year.

(f) Durability of Stabilised Roads.

The stabilised surfaces do not disintegrate during heavy rain; and whilst the first rains cause the formation of a thin, muddy surface layer, ageing causes this condition to decrease. The general opinion is that this disadvantage is negligible in comparison with the benefits conferred by stabilisation.

(g) Cost of Construction.

In Oakland County, Michigan, some 70 miles have been stabilised and the average cost per mile of 20-foot width has been as follows (data from "Roads and Streets", 1935, 78, 209) :—

Cost of gravel	.. ..	£ 180
Cost of other materials, labour and equipment	.. ..	£ 152
		—
Total		£ 333
		—

This is a high cost, owing to the large usage of gravel and the fact that long haulages were necessary to bring it to the site of operations.

On the other hand, another length of stabilised road constructed in Michigan was far cheaper, the costs per mile of 20 feet width being as follow :—

Cost of materials (including calcium chloride at £4.6 per short ton)...	.. ..	£ 13
Cost of labour, etc. ....	.. ..	£ 64
		—
Total		£ 77
		—

The main reason for the lower cost was that the gravel was on the site, and the clay cost about 3d. per cubic yard, as against 7/6d. in Oakland Company.

For the purposes of comparison, it is of interest to note that the cost of construction of concrete, or tar macadam roads is of the order of £5,000 per mile (of 20 feet width on existing foundations, and the figure can rise as high as £10,000 per mile) if it is necessary first to prepare foundation. (Roads and Road Construction Handbook. "The Concrete Journal").

(h). Cost of Maintenance.

For the Oakland Co. road it was necessary to blade the surface 8 times a year and to apply 8 tons of calcium chloride per mile in all. The average cost for 18 miles of road, worked out at £64 per mile per annum.

VII. EFFECTS OF CALCIUM CHLORIDE ON ROAD USERS.

There is no evidence to show that calcium chloride as used on roads is harmful to the hooves of animals, nor does it damage leather and motor tyres, tennis balls and rackets, nor corrode metal work. It is advisable for those handling the solution or solid to wear rubber gloves as prolonged contact with solutions containing calcium ions gives rise to characteristic skin lesions.

VIII. BIBLIOGRAPHY.

Stabilised Roads. "Engineering News Record" for 1934, a series of papers by W. R. Collings and L. C. Stewart of the Dow Chemical Company's Road Stabilization Department. "Roads and Streets", June 1935, an article by John H. Barr entitled "Stabilised Surfaces in Oakland County Michigan".

"Roads and Road Construction" January 1st 1936, page 14.

APPENDIX 4 TO ANNEX C.

Speech by Mr. W. A. Radice at the Business meeting of the Indian Roads Congress held at Lucknow in February 1937.

In 1928 the Indian Road Development Committee, in recommending the formation of a Road Conference, suggested that some of the subjects, it might discuss, might include :—

1. The classification of roads for the allocation of grants from Central Revenue.
2. The co-ordination of road programmes.
3. The co-ordination of road development with other system of transport.
4. *Technical questions relating to the construction and maintenance of roads and bridges and road research.*
5. The taxation of road transport.
6. Motor regulations.
7. *Statistics and intelligence.*

No doubts can be entertained regarding the vital importance of items 4 and 7 to a country needing a large scale road development programme but having insufficient funds. Yet all attempts made by the Road Conference to implement these proposals have so far proved sterile. In addressing you, it is my purpose to attempt to analyse the causes of failure and put before you proposals which I believe would be effective.

No matter how great are the benefits of decentralisation in administrative and executive matters, there can be no decentralisation of scientific knowledge and sound technical standards. The collection, sifting and codifying of road techniques

and practice must, of necessity, be a centralised activity. It is also unnecessary for me to try and convince you of the important economic results both in time and money resulting from the ready availability to all road engineers of up-to-date general specifications and reliable information on technical results and practice all over the world.

Perhaps a review of the methods successfully adopted by another department in tackling a similar problem may help to explain the thesis I am trying to develop.

Before the management of the East Indian, the G. I. P. and the Burma Railways was taken over by the State, the administration of most of the Railways in India was vested in the Boards of Directors of the various Railway Companies and over these government had not direct control. As now for roads, there existed for railways, in the period after the Great War a strong body of opinion that important savings could be gained by means of technical centralisation and the setting up of standards. Things were brought to a head when the growth of traffic and the demands of economic working produced ever increasing axle loads and the country was faced with a vast programme of bridge and permanent way renewals involving the expenditure of well over a hundred crores.

Just as in our own case, every administrative unit had its own technical advisers and executive and these often held irreconcilable views. Fortunately, for the country at large there was one existing and over riding power; the Government of India had assumed responsibility for the safety of the travelling public and in discharge of its responsibilities, it had powers to impose certain minima standards on all railways. These powers had been exercised by means of a set of rules governing the opening of new lines and the taking into use of new structures.

Unless these rules were strictly observed, Government could refuse to pass as safe for traffic any structure or line.

Apart from the restricted scope of their application, these were only rules, not specifications or established standards. Something more was needed. A beginning was made by summoning the Railway Bridge Engineers of India to annual meetings to discuss and advise government on changes to the rules, urgent technical problems and subjects for research work. The recommendations of this Committee of Bridge Engineers were circulated to the various railway administrations and their technical advisers and the answers tabulated, collected and circulated. Much good work was done and the country gained considerably from the independence of thought displayed by the members of the Bridge Committee, but any partial success which was scored was chiefly due to the absence of any compulsion on the various administrations to adopt the recommendations. By these means pertinacious opposition was avoided both in the Committee itself and outside of it with the result that valuable Codes of Practice came into existence available to all who cared to read.

Later, when most of the Indian Railways came under State management, the Committee of Bridge Engineers was replaced by a Standards Committee consisting of Engineers from all railways whether State managed or not. This Committee could be summoned at intervals to examine and make recommendations on every technical problem requiring solution. A permanent Controller of Standards with adequate assistance and money grants was appointed to implement such of the Committee recommendations as were acceptable to Government, to draw up specifications, to set up standards for all types of equipment and to conduct researches into questions where the available knowledge was insufficient. The output of this organization is now binding on all State managed Railways Administrations. This arrangement has been working for 6 and 7 years and the results have not only saved the country literally crores of rupees but have also provided a focus for the best technical brains in the service.

In the case of roads, the country is faced with a similar problem. The Road Conference has been set up and financed by the Petrol Tax and a considerable programme of road development is in course of preparation and execution. The extract from the Report of the Indian Road Development Committee quoted by me

as preface to these remarks and its acceptance by Government gives us sufficient assurance of official recognition of the importance and value of research and standardization.

This Congress, effectively representing the opinion of this country's Road Engineers, undoubtedly is of the same mind. Without funds or staff it has already laid down a series of definitions, a tentative standard or so, a standard specification for the design of road bridges of concrete and steel and will shortly consider way and means of undertaking a research into the impact effects of road traffic on bridges and road surfaces. Had it means and personnel, it would have gone even further. There can be no doubt, therefore, that the crying need for and the advantages of research and standardisation is recognised by all road interests and governments.

What we are asking ourselves, therefore, is, why this urge has produced so far so little.

Let us examine what has been tried. The Government of India created the post of Consulting Engineer for Roads to government. Committees of Chief Engineers of provinces have been summoned, but as might have been expected, immediately a consensus of opinion by the highest responsible officials was sought, considerations of the special conditions existing in each province and their responsibilities to their separate Provincial governments and their obligation to protect their particular interests predominated and unanimity became impossible, except in a few minor instances. It is with these discouraging results before him that, I think, the idea of creating the Indian Roads Congress germinated in Mr. Mitchell's mind. I may be wrong and I am open to correction but whether wrong or right the fact remains that by the creation of the Indian Roads Congress a weapon has been forged which in my opinion, will cut a way through the obstacles impeding progress. I will give you the reasons which have led me to this conclusion.

When they meet, the members of this Congress come together as Road Engineers, not as representatives of a province, a state or a firm. Their opinions on technical matters are binding on no one; they need not be primarily influenced by the guardianship of the interests of their particular employers but can serve the inexorable logic of known scientific facts and sound engineering experience and judgment. They are in the unique position of being, for the time, responsible to no one except to their own individual professional consciences because their expressed opinions within the Congress can only give birth to a corporate opinion binding nobody to anything. At the same time, owing to the very nature of the membership of the Congress, its corporate opinion has great weight and influence throughout the land. Here then is the body that can carry out research and standardization and produce authoritative results.

Should my views carry conviction, the next consideration I would put before you is the important matter of ways and means. Research and Standardization require money and permanent staff and these the Indian Roads Congress has not got. The Congress can, as government did in the case of Railways, appoint select Committees from its members to discharge for roads the functions that the Railway Standards Committee has discharged and is discharging for the railways, but in order to implement their decisions they need funds and a permanent Road Standards' Office staffed by a suitable Director and assistants. To the Road Standards' Office could be made available all technical information available to the Central and Provincial governments and the temporary services of experts in other departments in an advisory capacity. In view of the general state of public and official opinion, it would not seem an insuperable task to induce the Government of India to accept the thesis that the value of the labours of such an organization would be sufficiently important and effective to warrant charging its cost to the Road Fund.

My proposal, therefore, is this:—That the Indian Roads Congress should apply to the Government of India for official recognition that they are the best available means of implementing items 4 and 7 of the Indian Road Development Committee's Report of 1928 and that it should invite the Congress to table proposals and an estimate of cost of a programme of work extending over a series of years to be carried out under the control of the Consulting Engineer to the Government of India (Roads).

APPENDIX 5 TO ANNEX C.

Extracts from minutes of proceedings of the Second Meeting of the Council of the Indian Roads Congress held at the Municipal Hall, Lucknow, at 10 a.m. on Tuesday, February 23, 1937.

The Council considered and adopted the report of the Technical Sub-Committee (Appendix I) subject to the following comments and instructions:—

* * * * *

In connexion with the Sub-Committee's recommendations for the tests to be carried out on the test track, which were accepted, the Sub-Committee was instructed to consider what research, whether on a test track or otherwise, is possible in connexion with the effect upon water-bound macadam of mechanical transport and particularly the feature of corrugation.

ANNEX D.

Minutes of proceedings of Technical Sub-Committee of the Indian Roads Congress held at Hyderabad (Deccan), on 31st December, 1937.

PRESENT.

Mr. S. G. Stubbs, O.B.E., President of the Congress in the chair.

Mr. L. B. Gilbert.

Mr. R. Trevor-Jones.

Mr. C. D. N. Meares.

(Colonel G. E. Sopwith was invited during the discussion of items (1) and (3) of the agenda).

Mr. Jagdish Prasad, *Secretary*.

(1) The Committee considered Colonel Sopwith's criticism on the proposed code of practice for bituminous work and after some discussion came to the conclusion that the matter may be discussed again tomorrow.

(2) The Sub-Committee considered the suggestion of the Railway Board regarding all-India standard of width of combined road and rail bridges and decided to inform the Railway Board that the Committee feel that the minimum width of roadway between curbs should be 20 feet as laid down in the Indian Roads Congress bridge specification but before expressing their final opinion on the matter they would request the Railway Board to intimate the additional cost involved in increasing the clear road-width to 20 feet instead of 18 feet and 14 feet respectively where road is carried above or below the railway. Where road has to be carried outside the main girders at the same level as the railway, the clear roadway should not be less than 10 feet and facility should be provided for passing bays at intervals not greater than 300 feet.

(3) Regarding Colonel Sopwith's suggestion that tests on Alipore test tract regarding the performance of chips in surface dressing should be carried out using tar, the Sub-Committee decided to carry out these tests over a length of 100 feet in the middle of each straight length of the track, using 45 pounds of tar per 100 square feet and the quantity of chips as specified for bituminous work.

(4) The Committee considered the opinions of various Automobile Association regarding the distance at which road signs should be placed from the point of danger and decided that the normal distance should be a furlong and the minimum distance should be 400 feet, as originally suggested.

(5) Regarding the Indian Roads and Transport Development Association's suggestion to classify the roads according to the weight they can carry, the Committee decided that in view of Mr. K. G. Mitchell's paper which was to come for discussion at the next Congress meeting, the consideration of this question might be left till after that paper had been discussed.

(6) The Committee considered it desirable to lay down standards for vertical curves, sight distances, gradients, etc., through the medium of the code of practice on road work. The Committee considered the following standards suitable :—

(a) *Ruling gradients —*

for Plains roads	1 in 30
for Hill roads	1 in 20

Maximum gradient 1 in 15, in stretches not exceeding 300 feet. The gradient at curves should not exceed 1 in 30 and it should be flat at hairpin bends.

(b) In the case of vertical curves the maximum gradient should be 1/30 used over a horizontal distance not exceeding 200 feet, and the rate of change of gradient should not exceed 1/100 per hundred feet measured horizontally, and the summit of the curve should be made horizontal for a distance of 100 feet. A sight distance of about 550 feet will be thus automatically provided.

(c) *Radii of curve.*

Minimum radius of curves in plains roads	1000 feet.
Minimum radius of curves hill roads	.. 50 feet.

The question of widening and super-elevation to be considered later and incorporated in the Code of Practice for road work.

APPENDIX III

REPORT
OF THE
TECHNICAL SUB-COMMITTEE
TO THE
Council of the Indian Roads Congress
FOR THE YEAR 1938.

*(Considered and approved by the Council vide their resolution
No. 6. dated 17-2-39)*

We met on the 12th February, 1939 to consider the following agenda :—

- (1) Mr. Meares suggestion regarding experiments on base stabilization. (Memorandum attached—Annex E, page 38)
- (2) Classification of roads (Memorandum attached—Annex F, page 38)
- (3) Further experiments to be carried out on the Test-track (Memorandum attached—Annex G, page 45).
- (4) Standardisation of milestones and height and gradient posts (Memorandum attached—Annex H, page 48)
- (5) Question of printing the data regarding important road bridges in India which has been collected from the Provinces and certain states. (Memorandum attached—Annex I, page 49)
- (6) Certain papers on road construction by heat treatment using a special machine invented by Mr. Irvine (Annex J, page 49) for information.

1. We report :—

- (1) Where sub-grade conditions are such that maximum consolidation at optimum moisture content has been achieved, the inner road crusts will probably serve to carry the traffic. But local hammer action of occasional heavier loads may pulverize the surface of the sub-grade, and in course of time lead to separation by the formation of a layer of dust; and break down. In such cases "sub-oiling" may prevent pulverization. Mr. Stubbs has agreed to try this where the metalled surface is being widened over berms that have been very well consolidated and we recommend that it be tried experimentally in small lengths in places where the cost of soling makes it worth while to adopt special measures for sub-grade consolidation or the sub-grade is exceptionally good and soling is omitted.
- (2) We consider that the process of grouting from below with "oiled hoggin" (particulars may be had from the Secretary of the Congress on application) might be tried in small lengths, in

conditions where surface painted water-bound breaks down through failure of the main crust.

2. We recommend that if a uniform classification of roads is necessary the following would be suitable :—

(i) According to source of funds for up-keep —

Government
Local

(ii) According to importance —

I—Trunk roads or those connecting important towns.
II—Main roads of lesser importance than Class I.
III—Other roads fit for vehicular traffic.
IV—Roads not fit for vehicular traffic.
V—Bridle tracks.

(iii) According to the degree of interruption to traffic due to inadequate provision for cross-drainage—

A—Bridged and drained throughout.
B—Subject to slight interruption during the rains.
C—Subject to serious interruption or stoppage during the rains.

(iv) According to whether the surface is metalled or not

M—Metalled.
U—Unmetalled.

	<i>Examples.</i>
Government	I A (M)
Local	II B (M)
Local	III C (U)
Government	IV A (U)

3. We have recommended a future programme of tests to be carried out on the test-track. We have proceeded on the assumption that the first need is to investigate inexpensive surface treatments of macadam for rural road conditions. Reports will be issued as results are obtained.

4. We do not consider that any general standardisation of milestone is necessary or possible. We propose that the Secretary should circulate drawings of one or two suitable types for adoption if desirable, on new roads and for replacements when necessary. We do not consider that it is necessary to show elevation above sea-level generally. On ghat or hill roads this can be shown on milestones in the most convenient way on any particular type (e. g. "R L. 6120" in red). We do not consider that it is necessary to indicate gradients except where they exceed 1 in 10 and in such cases this can be done on a definition plate under the "steep hill" sign.

5. We do not advise that any expenditure should be incurred on printing and circulating the cost and other particulars of bridges recently collected until a few have been reproduced in "Indian Roads" and members can judge of the value that a book of particulars of say 100 bridges is likely to be.

6. The other members of the Committee wish to congratulate Mr. Gilmore and Messrs. Sen Gupta and Chowdhry on the excellence of the design of the test-track equipment which is largely original and the lay-out generally, and we consider that the thanks of the Congress are due to them for the immense amount of trouble they have taken. In this class of work adjustments and improvements are always necessary in the early stages but in this case, that seems to be more necessary in the preparation of samples for testing than in the testing equipment itself.

7. A copy of the minutes of our meeting held on the 12th February, 1939 as approved at a meeting held on the 13th February, 1939 are appended for more detailed reference (Annex K, page 50).

ANNEX E

To the Technical Sub-Committee's Report.

In his letter of the 28th January, 1938, a copy of which was supplied to Members of the Sub-Committee with my letter No. IRC 11 dated the 28th February, 1938, Mr. Meares suggested that the Government of India might assist in carrying out an experiment using a *layer of oil-bound filler* underneath the coat of stone metal when carrying out water-bound consolidation with a view to subsequent surface treatment. His idea was that the use of oil-stabilized-fines in this manner would result in a strong impervious crust at an extra cost of only Rs. 3/- to Rs. 4/- per hundred square feet.

The Consulting Engineer to the Government of India (Roads) expressed his inability to arrange for a special grant for this experiment and, as desired by him, the advice of the Technical Sub-Committee was sought. Mr. Stubbs, however, agreed to carry out some experiments in the Punjab. He has since informed that the cost of 'sub-oiling' is higher than the cost of 1-inch tar carpet and has discontinued further experiments.

The suggestion of Mr. Meares is now placed before the Sub-Committee for arriving at a final decision.

ANNEX F

To the Technical Sub-Committee's Report.

At its meeting held at Simla on the 29th August 1938, the Technical Sub-Committee considered the question of uniform classification of roads and keeping in view the necessity of classification which could be easily understood and could be conveniently referred to in all official correspondence and in schemes submitted to the Standing Committee for Roads, decided to classify roads as follows:—

- (i) According to source of funds for up-keep.

Provincial

Local

Military

- (ii) Accordingly to importance.

I—Trunk roads or those connecting important towns.

II—Main roads of lesser importance than Class I.

III—Other roads fit for vehicular traffic.

IV—Roads not fit for vehicular traffic.

- (iii) According to the degree of interruption to traffic due to inadequate provision for cross drainage.

A—Bridged and drained throughout.

B—Subject to slight interruption during the rains.

C—Subject to serious interruption or stoppage during the rains.

- (iv) According to whether the surface is metalled or not.

M — Metalled.

U — Unmetalled.

Examples

Provincial I A (M)

Local II B (M)

Local III C (U)

Provincial IV A (U)

When minutes of the Committee's meeting were circulated to Members for confirmation, Mr. Meares suggested for reasons given in his letter dated the 5th October 1938 (Appendix A, below) that the following classes might be substituted for classes III and IV :—

III — Other roads fit for motor traffic.

IV — Roads not fit for motor traffic.

Messrs. Stubbs, Trevor Jones and Arifuddin accepted the amendments proposed by Mr. Meares. Mr. Trevor Jones, however, suggested that a category for pack transport is essential and should be

“V — Hill Roads suitable for pack transport”.

Mr. Mitchell's views (Appendix B, page 40) are now placed before the Sub-Committee for consideration.

The Chief Engineer of the North-West Frontier Province, has again stretched the necessity of following Major Lang-Anderson's classification (Appendix C, page 40) which has since been accepted by the Military Engineering Services. The Sub-Committee may wish to reconsider this.

APPENDIX A TO ANNEX F

Copy of letter dated the 5th October 1938, from G.D.N. Meares, Esqr., C/o Standard Vacuum Oil Company, 8, Church Lane, Calcutta to the Secretary, Indian Roads Congress.

Subject :—Minutes of the meeting of the Technical Sub-Committee of the Indian Roads Congress held at Simla on the 29th August 1938.

I have the honour to acknowledge the receipt of your IRC 11 dated the 23rd September 1938 forwarding the minutes of the eighth meeting of the Technical Sub-Committee held at Simla on the 29th August 1938.

2. I have pleasure in confirming these minutes, subject to the comments hereunder :

3. Under the classification of Roads, Classifications III and IV both contain the word "Vehicular". I would point out that this term may lead to confusion, as some authorities may classify roads as fit for vehicular traffic when in point of fact the vehicles they have in mind are bullock-carts. Many such roads passable to bullock-cart traffic are quite unsuitable for motor traffic, and as the object of the classification is principally with a view to uniformity of nomenclature for motoring purposes, I would suggest that these two classifications be altered to read:

III—Other roads fit for motor traffic.

IV—Roads not fit for motor traffic.

4. If this amendment is adopted, it leaves no classification for hill roads etc., suitable only for packed transport but I do not believe that any special mention should be made of these.

APPENDIX B TO ANNEX F

I incline to agree with Mr. Meares but with the exception that I take Class IV to be pack-traffic roads and as such unfit for *any* vehicular traffic.

The difficulty could be met by sub-dividing Class III into roads fit for motor traffic and those fit for cart traffic only. It is extraordinarily difficult, however, to draw the distinction and if a road is unmetalled and just alluvial soil it may be quite good for motor traffic at certain seasons but nearly, if not quite, impassable at others. If it is in moorum or some such material not quite "metalling" it may be reasonably passable at all times. The solution is to add to "(iv) according to surface."

M—Metalled.

U.A.—Unmetalled but normally having a surface suitable for motor traffic except after heavy rains.

U.B.—Unmetalled.

K. G. MITCHELL,

25-11-38.

APPENDIX C TO ANNEX F.

Copy of letter No. 10664 P.W./270/IN., dated Peshawar, the 29th October, 1938, from A. Oram, Esqr., Secretary to the Government of the North-West Frontier Province, Public Works Department, to the Secretary, Indian Roads Congress, C/o. Department of Communications, New Delhi.

Subject:—Minutes of the meeting of the Technical Sub-Committee of the Indian Roads Congress held at Simla on the 29th August, 1938.

Reference:—Your No. IRC 11, dated the 23rd September 1938.

With reference to para (2) of the Minutes of the proceedings of the eighth meeting of the Technical Sub-Committee, I forward herewith copies of:—

1. This Office No. 2756 P.W., dated the 1st May, 1934, with Note.
2. Chief Engineer Northern Command No. CRNC/3406/E 2, dated the 18th May, 1938.
3. Chief Engineer Northern Command letter No. CRNC/3406/E 2, dated the 28th May 1935.

from which it will be seen that detailed proposals for the classification of roads have been made. These proposals have been accepted by the Engineer-in-Chief, Army Headquarters (India) for incorporation in the relevant M.E.S. Hand-Book.

It is suggested and strongly recommended that the method of standardisation should be settled in conjunction with the M.E.S. and on the lines suggested by Captain (now Major) Lang-Anderson, R.E..

* * * * *

Copy of a letter No. 2756/P.W., dated 1-5-34, from the Secretary to Government, North-West Frontier Province, Public Works Department, to the Chief Engineer, Northern Command.

Subject:—Road Classification.

With reference to your No. 12408/69/E.2, dated the 17th March 1934, I have the honour to forward herewith a Note on Road Classification by Captain W. C. Lang-Anderson, R.E.. I am to say that I concur in the proposed method of classification which I consider is simpler and better than that forwarded under your above quoted letter which I do not consider is suitable for civil requirements.

—————

Note dated the 27th April 1934, by Captain W. C. Lang-Anderson, R.E., on proposals for road classification.

1. Object.

Three bodies are concerned in roads. Firstly, the administrative authorities who decide the necessity of a road, its general alignment, and its general specification. The latter should consist purely of a statement of the nature of traffic to be carried and an estimate of the quantity of traffic. The administrative authority is not concerned with any other details except the provision of funds.

Secondly, the Engineer who works out a detailed design for the road, in accordance with the instructions of the administrative authority, and basing his design on past experience.

Lastly, the road user whether he be a staff officer working out a convoy timing or a private person planning a pleasure tour.

In deciding on a system of classifying roads, therefore, it is necessary to consider who requires the classification and in what way any method of classification can assist him. The object, in fact, is to convey information.

2. Information Required.

The administrative authority, except in its function as a road user, requires no information. It lays down the result it requires and leaves the Engineer to produce that result. The Engineer requires very detailed and diverse information. This information cannot be a mere number unless a very elaborate list of different types of roads is compiled.

The road user requires information on the following points only:

- (a) The nature of the surface and its capacity of standing up to the traffic under various climate conditions.
- (b) The width available for traffic.
- (c) Any restrictions to traffic due to lack of bridges, steep gradients, or defiles.

3. Types of Roads.

There are, broadly speaking, four general types of roads.

- (a) *The metalled road* giving a hard running surface carried on a solid foundation. It is capable of carrying heavy vehicles in all weathers. Whether

the surface has been treated or not is immaterial as a good water-bound macadam road is better than a worn-out treated road, and the existing state of repair of road cannot be shown in a permanent classification.

Further in a very few years all roads which are metalled, will be provided with treated surface.

- (b) *The stabilised road* of compacted finele or a mix-in-place mat. It is not provided with a built foundation, can carry fairly heavy traffic for a limited period in dry weather and only light traffic in wet weather.
- (c) *The Katcha road* consisting of the natural soil shaped and drained. It can carry only light traffic in fair weather and becomes impassable in wet weather.
- (d) *The Pack Track* which whatever its surface whether on account of narrowness or grade cannot take wheeled traffic but only pack animals.

All roads in the North-West Frontier Province come in one or other of these above classes. Further as far as can be foreseen, no new roads will be built which will not be in one of the above classes.

4. Method of Classification.

Classification is required in respect of

- (a) existing roads
- (b) new roads.

As the mileage of the former always greatly exceeds that of the latter, the method of classification must primarily be suitable for giving information about existing roads.

Now to classify roads into say six different classes numbered Class I, Class II etc., has the advantage of simplicity, and makes for easy reference but it has the following considerable disadvantages :-

- (a) Unless the road user knows the meaning of the classes they are unintelligible to him and frequently he will not be able to obtain the information.
- (b) The method tends to stereotype new construction into fixed specifications. Now the very reason for taking up the question of new classifications was that modern methods of road construction had outgrown the old M. E. S. standards which could not be used to describe the new roads. Such a state of affairs is likely to recur.
- (c) The terms are misleading. In common parlance Class I and 1st Class are apt to get muddled. For instance the Tank-Dera Ismail Khan Road would be called by the non-technical administrative authority or road user, a first class road (a car can cover the whole length of 40 miles in under an hour) but actually it is a class III road.
- (d) It does not help the engineer, as the definition can only be rather vague and he must, in any case, have much more detailed information about his roads.
- (e) Lastly a classification in six classes will not exactly cover all the varying types of road in the Province.

At the opposite extreme to a single number classification one can have a multiple number and letter classification, each letter or number denoting a particular quality or deficiency in a road such as

- (a) Foundation.
- (b) Surface.

- (c) Width.
- (d) Grades.
- (e) Bridges
- etc., etc.

But while this might be of use to the Engineer, it would be unintelligible to the road user unless he had a table of references. Thus one wants a system of classification which

- (a) is flexible
- (b) contains terms which can be easily memorised and from which the *intelligent* road user can deduce all the facts he wants.

The average road user must be assumed to be intelligent (one cannot cater for fools) and capable of judging for himself whether a road is suitable for his purpose provided he is given certain information. The information he requires is given in paragraph 2 above and it may be presumed that if he is given the type of road as described in paragraph 3 above he will know its suitability for his purpose.

5. *Method of Classification Proposed.*

It is, therefore, proposed that the following classification be adopted.

- (a) All roads be classified into one of the four types given in paragraph 3 as follows :
 - A Metalled
 - B Stabilised
 - C Kacha
 - D Pack.
- (b) Following the above initial letter will be a number indicating the width in feet of
 - (i) The metal in metalled roads
(The road user can assume a berm at least 4 feet wide on each side of the metal).
 - (ii) The whole road in other cases.
- (c) Following the width will come another letter indicating extent to which the road is bridged as follows :—
 - A Fully bridged for double traffic (18 feet or more)
 - B Fully bridged for single traffic at bridges
 - C Containing permanent causeways liable to floods of more than 2 hours duration, or roads liable to breaches such as Tank-Kaur.
 - D Unbridged.

(Note :—A road containing permanent causeways liable to flood interruption of less than 2 hours would be considered as fully bridged).

Examples.

Tank-D. I. Khan Road	..	..	A	9	A
Tank-Bannu Road	..	..	A	9	C
G. T. Road	..	..	A	16	A
H. T. Road	..	..	A	12	C
Kajuri Plain Roads	..	..	B	20	D
Nathiagali Road	..	..	D	12	D

6. *Civil Roads of Military Importance.*

The above system of classification permits of a graduated increase in, or reduction of, the standard of a road's different factors. For instance a C 18 B

road can be improved to a B 15 D road simply by adding a shingle surface or a B 8 D track can be improved to a C 12 D road by widening 4 feet, assuming graders are suitable. Again a metalled road, say A 9 C on which the traffic does not warrant the great expense of maintaining metalling can be reduced to a C 15 C road by shingling the whole width as the existing metal wears out, or an A 9 C road can be improved to an A 9 B road by building 12 feet wide bridges.

Under a single letter classification the alteration in the standard of a road can only be from one complete class to another, a process which will not always be feasible.

The variation of standard becomes of importance when one considers the relative requirements of the Civil and Military Authorities. The North-West Frontier Province Government does not require any particular system of classification. We know our roads, we know our traffic and we know the economic conditions affecting our roads. But as the Military Authorities in some cases demand a standard of road higher than Civil requirements some system of classification to indicate the difference is required. The proposed system allows of a higher standard being applied to a road by step, and the financial effect of each step can be ascertained.

For instance the Local Government may propose to build a B 20 C road. The military may demand that there should be 12 feet width of metalling thereby making it an A 12 C road. The difference in the cost of maintenance can be ascertained and the military would pay their share of the cost, say 50%. Again on a B 15 D road, the Military might demand single traffic bridges making it a B 15 B road. The difference in the cost of maintenance would be small and the Military need contribute nothing towards recurring costs but might be asked to help in the initial cost of bridging.

Thus the recurring cost of each step up in standard under the three particulars classified, viz. surface, width and bridging, can be calculated and tabulated. The Civil and Military Authorities could then classify all the roads according to their requirements and the difference could be immediately ascertained.

(Sd.) W. C. LANG-ANDERSON
Captain, R. E.

Executive Engineer and Personal
Assistant to Secretary to Government,
N.-W.F.P., P.W.D.

Copy of a Memorandum No. CRNC/3406/E 2, dated 18-5-1935, from Headquarters, Northern Command, Murree, to the Engineer-in-Chief, Army Headquarters, Simla.

Subject:—Re-classification of Roads.

Reference:—Correspondence ending with Headquarters N. C. No. 12408/77/E 2, dated 27-6-34, addressed to the Q.M.G. in India, Army Headquarters, Simla.

Will you kindly inform this office how the case with regard to the re-classification of roads now stands.

Copy of a Memorandum No. CRNC/3406/E 2, dated 28-5-35, from Headquarters, Northern Command, Murree, to the Chief Engineer, North-West Frontier Province, Public Works Department, Nathiagali.

Subject:—Re-classification of Roads.

Reference:—Your No. 001055. P. W. /490-W, dated 21-9-34, and correspondence ending with this office No. CRNC/3406/E 2, dated 18-5-1935.

The classification has been accepted and will be incorporated in the Handbook in due course.

ANNEX G

*Summary of suggestions made by the Provincial Chief Engineers for further tests on the Test Track.*1. *Chief Engineer, Bengal*, suggests the following tests:—

(1) Test of a water-bound brick metalled road of the standard usually adopted for district roads in the province. The road would consist of one layer of first class or picked jhama brick solking, 3 inches in thickness covered by a single layer of jhama brick metal, 6 inches in thickness measured loose. The metal would be broken to a gauge varying from 3 inches to 1 inch in size.

(2) Test of a water-bound stone metalled road of the same specification as (1) above, but with the metal consisting of stone of the types most commonly used in this province, e.g. Pakur trap, local quartz, gneiss etc.

(3) Test of a water-bound laterite metalled road of the same specification as (1) above but with the metal consisting of laterite nodules or pieces broken to about the same gauge as mentioned in (1) above.

(4) Test of roads of similar specifications to those given above, with the following:—

- (a) Half to be covered with a 2-inch bituminous carpet and
- (b) Half to be covered with a painting of bituminous surfacing material.

2. *Chief Engineer, United Provinces*, suggests:—

(1) That in order to ascertain the relative merits of different quantities of binder and chips experiments may be carried out using say

- (a) 56 pounds of bitumen or tar per hundred square feet with 5.6 cubic feet of chips.
- (b) 56 pounds of bitumen or tar per 100 square feet with 3.9 cubic feet of chips.
- (c) 34 pounds of bitumen or tar per 100 square feet with 4 cubic feet of chips.
- (d) 34 pounds of bitumen or tar per 100 square feet with 2.2 cubic feet of chips.

If there is no objection parallel series of tests with tar and bitumen may be carried out. The specification recommended by the suppliers of the binder used should be adopted.

(2) That a test should be carried out to ascertain the merits of an indigenous product known as DIGBOI bitumen compared to Spranex of similar grades. The former bitumen has not yet placed on the market but is likely to be available in due course.

(3) That tests should be carried out to ascertain the relative wearing qualities of surface treatment on over-burnt brick ballast as compared to similar treatment on an average quality stone.

(4) If it is considered desirable, tests on various proprietary binders one against the other may be carried out under exactly similar conditions.

3. *Chief Engineer, Central Provinces*, suggests that the wearing effects of different loadings and tyre-widths on water-bound macadam may be tested at the Test Track with a view to find out:—

- (a) What damage will be done if the present permissible laden weights of motor vehicles are increased and
- (b) What reduction in maintenance could be effected if each iron-wheel tyre of the common bullock-cart were to be 3 inches minimum width.

4. *Chief Engineer, Bihar*, in addition to the experiment which the Technical Sub-Committee has already agreed to carry out on the suggestions of Mr. W. L. Murrell using a primer (i.e. thinish binder like No. 1 road tar) and sand followed by a coat of thickish binder (like No. 2 Tar, Spramex or 105 Socony) and $\frac{1}{2}$ inch to $\frac{3}{4}$ inch size chips, has now suggested that as the cost of chips is high and that of sand, a good deal less, the second coat may be done as follows :—

“Only 70 percent to 80 percent of the usual quantity of chips to be used and these to be evenly spread on the 2nd coat of hot binder and rolled with a power roller 8 to 10 times so as to fix the chips thoroughly, but not so as to cause crushing of the chips.

Sand, as clear and coarse as possible, to an extent equal to the 30 to 20 percent shortage of chips plus 25 percent of its own volume, then to be spread evenly over the chips and well rolled.

The surface to be opened to traffic immediately in cases where hot binder has been used and after 36 hours where cut-back has been used as in the case of Socofix.

It is thought that the sand matrix will give lateral support to the chips and prevent their being crushed so easily by bullock-cart tyres.

5. *Chief Engineer, North-West Province* suggests :—

(1) From the point of view of the North-West Frontier Province which has a large mileage of painted roads, it is necessary to find out the most economical quantity of tar or bitumen and the best quantity of bajri to be used in surface dressing. Tests may be carried out on the following lines :—

- (a) Four gradings of bajri should be used, viz. :—

1/8-inch to 3/8-inch

1/4-inch to 1/2-inch

3/8-inch to 5/8-inch

and 1/8-inch to 5/8-inch

- (b) Varying quantities of tar or bitumen should be used with each of the above gradings in succession.

(2) A similar test using broken metal in carpets or mats should be made with a view to ascertaining the most suitable quantities, gradings and thickness of the mats, particularly in respect of heavy bullock-cart traffic which is the traffic for which such mats are primarily necessary.

6. *Chief Engineer, Orissa* has no suggestion but supports the views of the Sub-Committee that types of construction which are inexpensive and commonly used should be tested first.

7. *Secretary, Sind Public Works Department* suggests that tests to find out the relative merits of Quartz porphyry and limestone chips from Jassi and Kathar quarries respectively when used for surface dressing work may be carried out if tests with similar stones have not already been carried out on the test track.

8. *Chief Engineer of Mysore* suggests that tests may be carried out to find out comparative lives of plain macadam, the same surface painted and bitumen premix macadam under the mixed traffic conditions of bullock-carts and motor vehicles.

COMMENTS BY THE CONSULTING ENGINEER TO THE GOVERNMENT OF INDIA,
(ROADS), ON THE SUGGESTIONS OF :—

Chief Engineer, Central Provinces.

(a) The test track is not designed for high speeds, and can give no direct information about motor traffic.

(b) The proposal is attractive and indeed it is contemplated that the width of tyres of test vehicles can be varied. But the difficulty is that with ordinary carts on ordinary roads the width of contact may be much less than the width of the tyre and indeed almost a constant. On dusty water-bound macadam a wide tyre may save the road but on a clear surface the saving may not be noticeable. The experiment could be tried but there are other things more urgent. Moreover is there any great prospect of an increase in tyre sizes being practically possible? It is by no means certain that the tractive co-efficient is not increased.

Chief Engineer, North-West Frontier Province.

May be tried early. But surface polish by motor transport has to be considered.

Chief Engineer, Bihar.

(i) (a) and (b) for discussion. The size of chip depends on the quality of the stone, as well as on the binder. If also varying quantities of binder are to be used there will be a very large number of combinations. I agree as to the object but the full series may not be possible at present.

(ii) The relation of the maximum size of aggregate to the thickness of the carpet has been studied in many countries and is dealt with in text books and standard specifications. The proposal in its present form is too random. The proposer should, I think, suggest in what direction or directions a departure from modern practice should be investigated. When this work is being done on a reasonably large scale variation might be tried on an open road and a more specific problem put to the test track. In these experiments it is desirable to have a more or less definite proposition to investigate.

Secretary, Public Works Department, Sind.

The first thing is to get samples of the stone to compare with those tested. Elementary laboratory tests of adhesion can be made at the Test House. And if there is a problem for the track, a test can be made.

Chief Engineer, Mysore.

It was established long ago on the Brunswick test track and is recognised as a general truth that the wear of water-bound macadam under mixed traffic is far greater than the sum of the wear under each kind separately. The Alipore test track is not designed to reproduce mixed traffic. The wear of water-bound macadam under bullock-cart traffic alone is no measure of that under-sized traffic because the nature of the stone is a most important factor. I have no precise object in testing water-bound macadam but would be glad to discuss.

Chief Engineer, Bengal.

I find the same difficulty with most of these proposals.

Chief Engineer, United Provinces.

1. The amount of binder depends largely on the condition and nature of the surface being treated—but this may be tried.

2. Can be tried.
3. Very necessary.
4. Will come later.

A programme for the next set of lists will be worked out after the Committee has discussed these comments.

Copy of the letter No. 4684 Wks./38-3 dated, 23rd January, 1938.

From

H. R. Dogra, Esq., B.Sc.,
Chief Engineer, P.W.D. (Genl., Bldgs. and Roads)
Chempauk, Madras.

To

The Secretary,
The Indian Roads Congress,
C/o Department of Communications,
Government of India, New Delhi.

Sir,

Subject:—Roads—Test Tracks at Calcutta.

Reference:—Your letters Nos. IRC. 6 dated 4-10-38 and 22-11-38.

I would suggest that in the next batch of tests on the test tracks, tests with Pallavaram blue granite metal and chips be included, as these materials are largely used for road works in and around Madras. One section of the test track may have a soling of granite stones and another with laterite stones, to note the effect of the difference in hardness of the two soling materials. The required quantities of materials will be sent on further hearing from you.

2. It is mentioned in a foot note under Appendix 'A' to the specification that the trench to be formed for the track will be 12 inches deep to receive the soling and two coats of metal. The soling is to be 6 inches thick. It is presumed that each of the two coats of metal will be $4\frac{1}{2}$ inches thick before consolidation, and the 1-inch clay binding is to be laid under each layer of loose metal ($4\frac{1}{2}$ inches thick)—to be worked up through the interstices by rolling.

3. The specification mentions the use of 4-ton roller for rolling over the fine aggregate spread after the application of bitumen. Burmah-Shell generally advise the use of 8 to 10-ton rollers. I should think 8 to 10-ton or at least 6 to 8-ton rollers are necessary for rolling over the granite chips.

ANNEX H.

To the Technical Sub-Committee's Report.

The question of standardisation of (a) milestones, (b) signs to indicate altitudes and gradients together with principles to govern their erection, has been referred to the Government of India by certain associations and Provincial Governments. The advice of the Roads Congress is necessary.

So far as is known, there are no international standards for milestones or the signs in question. Gradients appear to be of interest only when they are exceedingly severe say, steeper than 1 in 10 and such cases can be treated by the erection of

notice-boards or by an explanatory plate fixed under Indian Standard Sign, Part B, No. 10. Height above sea-level can be marked on milestones on a suitable part depending on the design.

The design of a height and gradient post as suggested by the Safety First Association of India will be found at Appendix I, and designs of milestone as used in the Punjab, United Provinces and Central Provinces are at Appendices II, III and IV.

ANNEX I.

To the Technical Sub-Committee's Report.

At the Third Indian Roads Congress held at Lucknow in February 1937, it was suggested that it would be valuable to get out figures for the cost of road bridges built in various Provinces and States in the past few years on the basis of elevation area to bottom of foundations, the roadway width being separately stated. As it was thought that the information would be of great interest and value in selecting the best type of bridge for a given set of conditions and as a guide in preliminary estimating, the information specified in the attached form has been collected from provinces and certain states in respect of about 90 bridges.

It is for consideration whether the particulars may be published in book form and made available for sale. If some of the drawings are omitted or redrawn, it is estimated that the expenditure would be about Rs. 1,500 for printing 1,000 copies in which case the price of the book for sale to non-members might be Rs. 3/- net.

ANNEX J.

A few points of importance about the machine are:—

- (1) 6 feet width is treated in one traverse of the machine.
 - (2) Depth burnt is 2 inches to 4 inches according to soil.
 - (4) Rate of burning soil is 40 feet per hour.
 - (3) At 850 degrees Fahrenheit moisture is all evaporated from soil. Beyond 1100 degrees Fahrenheit, fusion and cementation of particles takes place;
1300 degrees Fahrenheit to 2500 degrees Fahrenheit are limits of carrying on treatment;
1700 degrees Fahrenheit is the average temperature used for black soils.
 - (5) Soils to be treated should have a high clay content.
 - (6) The quantity of burnt material is not equal to rock or hard metal in durability (Deval Abrasion loss 14 to 27 per cent and specific gravity about 2.0). (It may be considered as equivalent to laterite).
 - (7) The machine is 33 feet long, 8 feet 7 inches high and 9 feet wide and weighs about 26 to 27 tons. Cost £3,000. F.O.T. Works (England).
 - (8) Cost of heat treated roads (12 feet wide) in Australia is about 700 pounds per mile, (single layer of burning).
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ANNEX K.

Proceedings of the Technical Sub-Committee meeting on the 12th February, 1939 as approved at a meeting held on the 13th February, 1939.

PRESENT.

Mr. S. G. Stubbs, O.B.E., *Chairman.*

Mr. K. G. Mitchell, C.I.E.

Mr. C. D. N. Meares.

Mr. Syed Arifuddin.

Mr. J. A. Stein.

Mr. E. F. G. Gilmore.

Mr. N. N. Sen Gupta.

Mr. A. N. Chowdhry.

Mr. Jagdish Prasad, *Secretary.*

1. *Mr. Meares' proposals regarding base stabilization, etc.*

Decided. (1) That the effect of "oiling" (with asphaltic oil) the well consolidated berm sub-grade—upon which a wearing coat is being laid direct in the Punjab in the course of widening, will be tried by Mr. Stubbs. It has been found in the Punjab that the berms of old metalled roads a few inches below the surface have been superlatively consolidated (probably, in the ordinary course of nature, at optimum moisture content) and that for widening the metalled carriage-way no soling is necessary. The addition of an asphaltic binder will give that plasticity—as opposed to friability of the top layer of the sub-grade which is necessary to prevent the formation of an insulating and gradually increasing dividing layer of dust.

(2) Recommend that in ordinary macadam consolidation whether to be surface painted or not Engineers should try in suitable small lengths the effect of laying the loose metal on a hoggin—asphaltic oil mix so as to get "inverted loaded grouting."

2. *Classification of roads—*

Decided. That it would suffice if in "(ii) According to importance" the words "motor transport" were substituted for the words "vehicular traffic" in III and IV. This to be done and the classification otherwise to remain, except for the addition of a class under "(ii) According to importance" of "V Bridle Tracks."

3. *Standardization of milestones and height and gradient posts.*

Decided. (1) That it would be a waste of money to replace all existing milestones by a standard type and that no province is likely to do this. It will suffice to circulate copies of satisfactory types for adoption on new roads and for replacement.

(2) That normally, unless otherwise done already, as far as possible, heights above sea-level should be shown on milestones where there are considerable changes in level.

(3) That it would be a waste of money to attempt to show gradients everywhere or even on long hill and ghat roads where they do not vary much from the ruling gradient. For safety and general interest it will suffice to indicate gradient steeper than one in ten on definition plates affixed below the standard "steep hill" sign.

4. *Question of printing data regarding important road bridges in India.*

Decided. That a selection of half a dozen to a dozen sets of particulars be published in "Indian Roads" in order to ascertain whether there would be any demand for a complete series.

5. *Papers regarding heat treatment of earth roads.* (The Irvine Road machine). The papers were for information only.

6. *Further experiments to be carried out on the Test Track.*

Decided after a visit to the track—That (1) after a few hours further demonstration run, the plant should be stopped and the whole track re-rolled with a ten or twelve-ton roller.

(2) The testing should then be resumed in the present wheel ruts with the present loading of the carts until destruction.

(3) Test samples about 6 inches by 6 inches should be cut out (patch with a premix) immediately and at fairly frequent intervals until destruction, to determine the initial and subsequent breaking down of the chips by extraction of binder and sieve analysis.

(4) When the existing tracks or ruts have been so destroyed that the test cannot continue, the present test to be stopped and recommended on another set of ruts by adjusting the machinery. (It may be possible to run one machine only). The point at which the test is to be stopped to be determined by Messrs. Sen Gupta and Stein in consultation. If one or two lengths prove to be greatly superior to others it may be necessary to patch the ruts so as to allow the testing of the good sections to be continued for sufficient time to evaluate their superiority.

(5) When a start is made upon new ruts (on one rail) the carts should be loaded to 2,000 pounds only until the tracks have surfaced up and the load should be increased later in the discretion of those in charge. On the other rail the same should be tried with sanding of the chips before the carts are laid on to see if crushing is reduced.

(6) Further tests. The series should be continued of testing various chips with different binders as at present and, in order that there should be no doubt in comparison, the chip will be used with the same stone in the water-bound macadam course. For this it will suffice to cut out and relay with new material in four strips 18 inches wide each. Stones to be so tested are those proposed by the Chief Engineers of Madras (one sample) and Sind (two samples) and any others proposed.

(7) The relative behaviour of the various chips should be compared with the "ranking" of the stone by the Deval machine.

(8) The varying of the proportion of chips to binder (U.P. proposal) and the use of sand to blind the chips (Bihar proposal) should come next.

(9) Thereafter the following to be tried out as convenient :—

- (a) Brick ballast primed and surface painted with binder and good chips;
- (b) Brick ballast with stone "grafted on with a primer" if necessary and painted with binder and chips;
- (c) Brick and stone ballast with "inverted loaded asphalt grout" painted with binder and chips;
- (d) The effect of varying the size of the chips. (The optimum size of chips is probably determined by the quality of the stone and the unit weight of the traffic. It may be possible on the track to determine the optimum size of chips for different qualities of stone, but more results are necessary before it can be said how far this will be useful).
- (e) The effect of water.

(10) It is probably useless to test thin premix carpets of less than 2 inches consolidated. But the comparative tests of representative specifications of premixes and grouts may be made.

(11) Later, cement concrete in different thicknesses and to different specifications can also be tried.

(12) If possible a monthly report on the work in the track and proposals for the next tests then contemplated will be issued to the Technical Committee who will send in any comments or criticisms they may have.

APPENDIX IV.

DISCUSSIONS ON THE RESOLUTION REGARDING RESTRICTIONS ON "RIBBON DEVELOPMENT".

(which took place on 17th February 1939.)

Lt.-Col. H. C. Smith:—There is the important point which Mr. Mitchell and also Mr. Trevor-Jones raised. That is with regard to legislation and the possibility of this Congress passing a resolution recommending to Provincial authorities and the Indian States the desirability of passing legislation. I have drafted a rough resolution to which if this Congress agrees a final draft will be made and submitted to you after lunch. I will read out this rough draft:—

Resolution :

"This Congress, in view of the evils of "Ribbon Development" on and obstruction of roads and the danger and obstruction to the growing road traffic which they cause and of the heavy cost of restoring an adequate width free of obstruction, recommend to the Provincial authorities and Indian States that immediate legislation be undertaken to restrict this type of development".

If this meeting agrees to something on these lines, the final draft might be submitted after lunch.

Mr. S. G. Stubbs (Chairman):—In regard to the proposal of Colonel Smith, the following resolution will be passed urging that immediate legislation be undertaken. This is the resolution:—

"This Congress, in view of the evils of "Ribbon Development" on and obstruction of roads and the danger and obstruction to the growing road traffic which they cause and of the heavy cost of restoring an adequate width free of obstruction, recommend to the Provincial authorities and Indian States that immediate legislation be undertaken to restrict this type of development".

Have you any suggestions to make about this resolution?

Mr. G. B. Vaswani (Karachi):—Will the words "Provincial authorities" be taken to mean "Provincial Governments"? Will it not be suitable to put the words "encroachment on the developed land" instead of "this type of development"?

Mr. S. Bashiram (Panjab):—I do not think it is possible to give immediately our considered views.

Mr. S. G. Stubbs (Chairman):—Your resolutions should be framed after due consideration by the Council.

Mr. S. Bashiram (Punjab):—It should be taken up tomorrow.

Mr. S. G. Stubbs (Chairman):—I think perhaps it will be a wiser course if we all thought about it.

Mr. S. Bashiram (Punjab):—I will further suggest that there should be a forwarding letter by the Council in which they can amplify the reasons underlying the resolution proposed.

Mr. G. B. Vaswani (Karachi):—You may consider all these points but I think it will perhaps be better if we were given time to consider it, and we might be able to move a slightly modified resolution.

Lt.-Col. H. C. Smith:—The only difficulty is the Council have had three meetings, and I do not know whether they are going to have another, and after tomorrow's meeting, of course, the new Council will come in. It is rather difficult. I think we have to consider it during the lunch interval and pass the resolution afterwards. I really do not think that we can call another Council meeting to consider this, and if that is so, it will be put off till a considerable time.

Mr. S. G. Stubbs (Chairman):—Shall we take it up after lunch?

Mr. S. Bashiram (Punjab):—The present proposal should be read out slowly, so that we may digest it.

Lt.-Col. H. C. Smith:—(Reads the proposed resolution again).

"This Congress, in view of the evils of "Ribbon Development" and existing encroachment on and obstruction of roads and the danger and obstruction to the growing road traffic which they cause and of the heavy cost of restoring an adequate width free of obstruction, recommend to the Provincial authorities and Indian States that immediate legislation be undertaken to restrict this type of development".

Mr. S. G. Stubbs (Chairman):—We will take this up again after lunch after you have had time to consider it and digested it with your lunch. (Laughter).

(Continued after lunch)

Mr. S. G. Stubbs (Chairman):—Before continuing the discussion on Papers we will take up the question of Resolution which we briefly discussed before lunch on "Ribbon Development". Mr. Bashiram asked that he might be given time to digest the question, and I presume that members have had this time to digest the question. Has anybody else got further suggestions to make?

Mr. T. Lokanathan (Coimbatore):—In this connection you may be interested to know what occurred in the Madras Presidency where also this question of encroachment is giving us a lot of trouble. There was a

circular issued about four years ago by the Madras Government to the effect that when the encroachments on a road became so many that they could not all be reasonably evicted, a detour road might be formed with advantage. I just mention this to show that any attempt on our part to keep back encroachments would be like the policeman trying to keep out the crowd and finally letting the crowd have its own way.

Mr. S. G. Stubbs (Chairman):—The question in issue is whether the Congress agree with this resolution or not, and on what lines it should be made.

There is no objection to that. That is understood, I presume.

Mr. S. Bashiram (Punjab):—Will you kindly read out the resolution once again?

Mr. S. G. Stubbs (Chairman):—(Reads the resolution).

Rai Sahib Fateh Chand (United Provinces):—I suggest that the resolution be so worded as to apply to Ribbon Development on District Board and Municipal roads as well, and the definition of the word "Ribbon Development" be made clearer with reference to local roads, where occupation of the road-land is allowed by the Boards under different names both temporarily and permanently. My point in raising this point is that the Ministers might keep the local roads in view while taking action on this resolution. I hope the Chief Engineers will put such an interpretation to the resolution as to include local roads (even if the wordings are not changed) when their advice is sought by the Honourable Ministers on this resolution, so that ribbon development on local roads be controlled side by side with its control on the Public Works Department roads.

Mr. S. G. Stubbs (Chairman):—We all know what Ribbon Development is. The question is whether we should first pass the resolution and then ask the Provincial Governments to take action.

(The resolution was then put to the meeting and carried unanimously).

APPENDIX V.

TOURS AND OTHER FUNCTIONS HELD DURING THE FIFTH
SESSION OF THE INDIAN ROADS CONGRESS,
CALCUTTA, FEBRUARY 1939.

Monday, February 13, 1939.

The delegates assembled near the South Western Gate of Eden Gardens near Bandstand, at 8-30 a.m., and proceeded from there in taxis to inspect the Calcutta-Jessore Road.

This road was one of the first in Bengal to be improved from the Central Road Fund. The work of improvement was first taken up in 1930 and extended from BELGACHIA (mile 3 furlong 6-646 feet) to BARASET (15 M. P.). Owing to the intensity of traffic it was decided to put down some of the higher specifications of types of road on the 3-1/2 miles between BELGACHIA to DUM DUM (9 M. P.). From DUM DUM to BARASET the surfacing was two coats of paint only. The higher specifications put down between BELGACHIA and DUM DUM were:—

STONE SETT PAVEMENT, CEMENT GROUTED, OVER 4 INCH LIME CONCRETE. This was laid for 2 furlongs 379 feet on either side of the tramway lines in 1931-32.

The cost of surface treatment is Rs. 52/10/- per hundred square feet.

PRESENT CONDITION.—The present condition is satisfactory though the length of the road is subjected to heavy bullock-cart traffic. There is however a straight wide joint between the stone sett pavements of the Tramway and the Communications and Works Department, there being no bonding between the two.

COMMENCING 4M. 2F. 283 FEET.

(i) CEMENT CONCRETE IN 2 COURSES, BOTTOM 5-INCH THICK (1:2:4) AND WEARING COURSE 2-INCH THICK (1:1:2);—laid for 2 furlongs 193 feet in August 1931 over water-bound road with trap stone metal. Cost per hundred square feet—Rs. 75/6/-.

(ii) 7-INCH THICK CEMENT CONCRETE IN 1 COURSE (1:2½:3½);—laid for 2 furlongs 101 feet in October 1931 over water-bound macadam road with trap stone metal. Cost per hundred square feet Rs. 70/13/-.

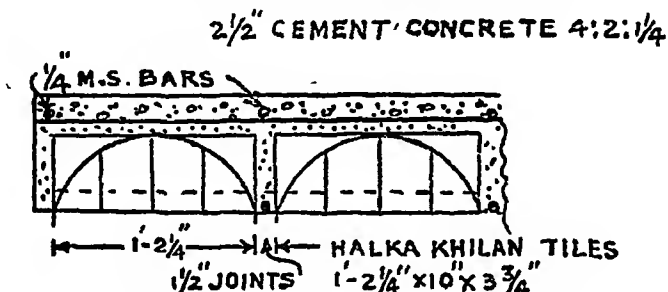
(iii) CEMENT CONCRETE IN 2 COURSES BOTTOM 5-INCHES THICK (1:2:4) AND WEARING COURSE 2-INCHES THICK (1:1:2) WITH DOUBLE REINFORCEMENT. Top reinforcement is of B. R. C. fabric No. 9 and bottom reinforcement is 3/8-inch mild steel bars, 6 inches apart both-ways. This was laid for 417 feet in March 1933. Reinforcement had to be used on account of defective soil in foundation. Cost per hundred square feet Rs. 103/8/-.

PRESENT CONDITION.—Present condition of the above three stretches of concrete is very satisfactory though this is subjected to heavy wheeled cart and other traffic. There has been practically no expenditure on maintenance except for filling up expansion joints occasionally.

So far, any difference in the wearing properties of the various specifications is not apparent.

COMMENCING 4M. 7F. 334 FEET.

(i) 6½-INCH THICK HALKA KHILAN (PATENTED, TILED REINFORCED CONCRETE (4:2:1½) (*vide* diagram below.)



This was laid for a 66 feet length, in March 1933. Cost per hundred square feet Rs. 55/9/-.

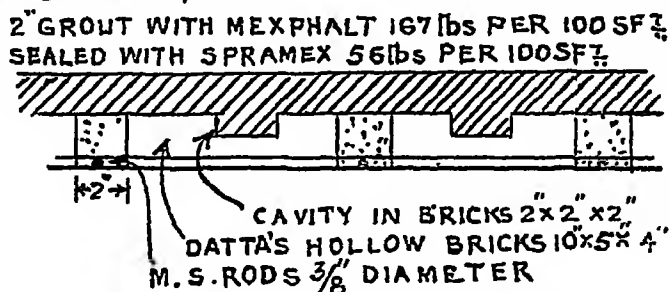
PRESENT CONDITION.—This has both longitudinal and transverse cracks

(ii) 2-INCH GROUT WITH TRINIPHALT AT 167 POUNDS PER 100 SQUARE FEET AND SEAL WITH SPRAYPHALT AT 56 POUNDS PER 100 SQUARE FEET. This was laid on a 80 feet length in May 1933. Cost per hundred square feet Rs. 25/-

PRESENT CONDITION.—Good.

This short length of road was carpeted in 1932 with a 2-inch concrete bitumen mixture 4 of stone, 2 of sand and 1 cubic foot of cement mixed with Colfix. This was a complete failure as the matrix never set.

(iii) DATTA'S REINFORCED BRICK AND CEMENT CONCRETE WITH WEARING COURSE 2-INCH THICK MEXPHALT GROUT WITH SPRAMEX SEAL (MEXPHALT AT 167 POUNDS PER HUNDRED SQUARE FEET, AND SPRAMEX FOR SEAL AT 56 POUNDS PER HUNDRED SQUARE FEET, (*vide* diagram below.)



This was laid on a 30 feet length in March 1932. Cost per hundred square feet Rs. 65/-.

PRESENT CONDITION.—Good.

(iv) DATTAS BRICK AND CEMENT CONCRETE WITHOUT REINFORCEMENT.—(diagram same as in (iii) above except that the reinforcement is omitted and bitumen grout is replaced by cement concrete). This was laid on a 30 feet length in March 1932. Cost per hundred square feet, Rs. 47/-.

PRESENT CONDITION.—This has cracked in places.

(v) DATTAS BRICK WITH REINFORCED CONCRETE (1: 1½: 3) (diagram same as in (iii) above except that bitumen grout is replaced by cement concrete). This was also laid on a 30 feet length in March 1932. Cost per hundred square feet Rs. 53/5/-.

PRESENT CONDITION.—Good.

(vi) 2-INCH PREMIX CARPET-BASE COAT WITH HIGH VISCOSITY ROAD TAR AT 4.5 POUNDS PER CUBIC FOOT OF STONE METAL AND STONE CHIPS AND TOP COAT WITH TAR No. 3 AT 4 POUNDS TO 6 POUNDS PER CUBIC FOOT OF STONE CHIPS.—This was laid for one furlong in April 1938. Cost per hundred square feet, Rs. 32/12-.

PRESENT CONDITION.—Good.

(vii) 2-INCH GROUT WITH MEXPHALT AT 133 POUNDS PER HUNDRED SQUARE FEET AND SEAL WITH SPRAMEX AT 56 POUNDS PER 100 SQUARE FEET.—This was laid for 5 furlongs in 1931-32. This length was repainted with Spramex in 1937-38. Cost per hundred square feet, Rs. 24/11/-.

The length we have just passed over is interesting as it was an attempt at economy by reducing the amount of matrix. 133 pounds per hundred square feet were applied with a seal of 56 pounds per 100 square feet. The quantity of bitumen used was obviously insufficient as the surface pot-holed badly and has required a good deal of maintenance. The surface now is very rough.

COMMENCING 5M. 6F.

(i) 2-INCH GROUT WITH SOCONY ASPHALT 101 AT 167 POUNDS PER 100 SQUARE FEET AND SEAL WITH SOCONY ASPHALT 105 AT 56 POUNDS PER 100 SQUARE FEET.—This was laid for 4 furlongs in 1931-32. Cost per 100 square feet Rs. 24/11/-.

PRESENT CONDITION.—Very satisfactory. There has been practically no cost of maintenance so far.

(ii) 2-INCH GROUT WITH PITCH AND TAR (2:1) AT 189 POUNDS PER 100 SQUARE FEET AND SEAL WITH PITCH AND TAR (2:1) AT 56 POUNDS PER 100 SQUARE FEET.—This was laid for 6 furlongs in March 1932. Cost per 100 square feet Rs. 19/10.6. 7th and 8th Furlongs were painted with Spramex in 1935-36.

PRESENT CONDITION.—Fair. Signs of wear are noticeable in places.

(iii) 2-INCH GROUT WITH SOCONY ASPHALT 101 AT 176 POUNDS PER 100 SQUARE FEET AND SEAL WITH SOCONY ASPHALT 105 AT 56 POUNDS PER 100 SQUARE FEET laid in 1933-34. Cost per 100 square feet, Rs. 26/4/-.

PRESENT CONDITION.—Satisfactory.

The 8th mile was originally devoted to grouting with various emulsions. These were not a success, the surface pot-holed badly with the result that the greater portion of the road had to be picked up and a fresh 2-inch grout laid two years later (1933-34). The greater portion of this mile is now of the specification given above for socony.

COMMENCING 8M. OF

(i) 2-INCH TEXACO PAVING CEMENT AT 165 POUNDS PER 100 SQUARE FEET AND SEAL WITH NO. 96 AT 56 POUNDS PER 100 SQUARE FEET. This was laid for a length of one furlong in April 1932. Cost per 100 square feet Rs 24/8/-.

PRESENT CONDITION.—This is showing signs of failure especially on the eastern half of the road.

(ii) 2-INCH PREMIX CARPET WITH HIGH VISCOSITY ROAD TAR AND SEAL WITH TAR No. 1. This was also laid over one furlong in May 1932. Cost per 100 square feet Rs. 29/3/-. This was painted with Spramex in 1934-35.

PRESENT CONDITION.—This is also showing signs of failure, especially on the eastern half of the road.

COMMENCING 9M. OF

2-INCH GROUT WITH PITCH AND TAR (5:3) AT 215 POUNDS PER 100 SQUARE FEET AND PREMIXED CHIPS AT 4.5 POUNDS OF TAR AND PITCH (1:1) PER CUBIC FOOT OF STONE CHIPS AND SEAL WITH SPRAMEX AT 35 POUNDS PER 100 SQUARE FEET. This was laid in 8 furlongs in 1937-38. Cost per 100 square feet Rs 24/-.

PRESENT CONDITION.—Good.

This road was water-bound with trap stone metal and painted with 2 coats of Spramex in December 1932. Painting did not stand up to the traffic, so a grout was put down in 1937-38. The intensity of traffic over 18 feet width in 24 hours is 3019 tons as per census taken in June 1938, (page 83).

EXPERIMENT WITH CUTBACK OF BITUMEN.

13TH MILE (14 FURLONGS).

CONDITION BEFORE TREATMENT.—This mile was very wavy but had a thick crust formed by periodical repaintings. On digging trial holes, it was found that the road had from 2 inches to 3 inches of metalling only. It was decided to resection the road and to utilize the old asphalt crust.

TREATMENT.—The crust was picked up and broken to 1-inch pieces. The road was scarified, the base dressed level and a layer of blinding material laid on the base, over which the new metal together with some old metal, was laid. Dry rolling was done for some time after which the road was profusely watered. Rolling was continued until the hoggin from below creamed up. The broken pieces of the crust were then spread over the surface and rolling continued until these pieces were firmly lodged in the surface voids of the metal. The road was kept closed to traffic and allowed to dry for several weeks.

Socony Liquid Asphalt No. 2 was then applied at 2 gallons per 100 square-feet over the first two furlongs and at 3 gallons per 100 square feet over the next 2 furlongs. After an interval of 48 hours it was noticed that the asphalt of the old crust was completely dissolved by the liquid asphalt and the road was flooded with bitumen. Sand was spread at 2-3 cubic feet per 100 square feet and the road was opened to traffic.

The second coat with Socony Asphal Grade 105 (80/100 penetration containing 99.9 percent bitumen) was given after one year in March 1938 at 30 pounds per 100/- square feet and blinded with 4 cubic feet of stone chips.

PRESENT CONDITION.—Fair, though there are signs of wear in places.

COMMENCING 13M. 0F.

(1) **2-COAT PAINTING WITH BITUMALS @ 84 POUNDS PER 100 SQUARE FEET.** This was done in one mile in December 1932. Cost per 100 square feet Rs. 9/12/-. This was again painted, one coat with Sprayphalt in 1933-34; and repainted with one coat of Socony asphalt 105 in 1937-38.

PRESENT CONDITION.—Fair, though there are signs of wear in places.

COMMENCING 14M. 0F.

(1) **PAINTING 2 COATS WITH COLFIX @ 78 POUNDS PER 100 SQUARE FEET.** This was done in 1 mile in April 1932. Cost per 100 square feet Rs. 8/12/-. This was painted again with one coat of Socony asphalt 105 in 1933-34.

PRESENT CONDITION.—Fair, though there are signs of wear in places.

This ends the work that was carried out in the 1930-32 programme.

From now onwards except for two experimental lengths, there is no surface treatment which is less than 2 inches thick. The various treatments are as follows :—

COMMENCING 16M. 2F.

(i) **2-INCH GROUT WITH PITCH AND TAR (5:3) @ 260 POUNDS PER 100 SQUARE FEET AND SEAL WITH SPRAMEX @ 45 POUNDS PER 100 SQUARE FEET.** This was laid for 5 furlongs in March 1936. Cost per 100 square feet Rs. 21/14/6.

PRESENT CONDITION.—Good.

COMMENCING 16M. 7F.

(i) **2-INCH GROUT WITH TRINIPHALT @ 170 POUNDS PER 100 SQUARE FEET AND SEAL WITH SPRAMEX @ 45 POUNDS PER 100 SQUARE FEET.** This was laid on one furlong in March 1936. Cost per 100 square feet Rs. 20/7/2.

PRESENT CONDITION.—Good.

(ii) 2-INCH GROUT WITH TRINIPHALT @ 178 POUNDS PER 100 SQUARE FEET AND SEALED WITH SPRAYPHALT @ 44 POUNDS PER 100 SQUARE FEET. This was laid for 7 furlongs in May 1936. Cost per 100 square feet Rs. 25/1/-.

PRESENT CONDITION.—Good.

(iii) 2-INCH GROUT WITH PITCH AND TAR (2:1) @ 215 POUNDS PER 100 SQUARE FEET AND SEALED WITH SPRAYPHALT @ 44 POUNDS PER 100 SQUARE FEET. This was laid on one furlong in May 1936. Cost per 100 square feet Rs. 24/8/4.

PRESENT CONDITION.—Good.

COMMENCING 18M. OF.

(i) 2-INCH SHELCRETE WITH MEXPHALT AND SHELMAC (2:1) @ 160 POUNDS PER 100 SQUARE FEET. This was laid for 6 furlongs 394 feet in June 1936. Cost per 100 square feet Rs. 19/-.

PRESENT CONDITION.—Good.

(ii) 2-INCH GROUT WITH MEXPHALT @ 177 POUNDS PER 100 SQUARE FEET AND SEALED WITH SPRAMEX @ 41 POUNDS PER 100 SQUARE FEET. This was done for one furlong 266 feet in April 1937. Cost per 100 square feet Rs. 19/-.

PRESENT CONDITION.—Good.

COMMENCING 21M. OF.

(i) 2-INCH GROUT WITH MEXPHALT @ 175 POUNDS PER 100 SQUARE FEET AND SEALED WITH SPRAMEX @ 45 POUNDS PER 100 SQUARE FEET. This was laid for one mile in April 1936. Cost per 100 square feet Rs. 23/5/1.

PRESENT CONDITION.—Good.

(ii) 2-INCH GROUT WITH MEXPHALT @ 177 POUNDS PER 100 SQUARE FEET AND SEALED WITH SPRAMEX @ 38 POUNDS PER 100 SQUARE FEET. This was laid for one mile in April 1938. Cost per 100 square feet Rs. 22/14/5.

PRESENT CONDITION.—Good.

COMMENCING 23M. OF.

2-INCH GROUT WITH SOCONY ASPHALT 101 @ 176 POUNDS PER 100 SQUARE FEET AND SEALED WITH SOCONY ASPHALT 105 @ 44 POUNDS PER 100 SQUARE FEET. This was done in 2 miles in June 1936. Average cost per 100 square feet Rs. 22, 14/8.

PRESENT CONDITION.—Good.

COMMENCING 25M. OF.

2-INCH GROUT WITH SOCONY ASPHALT 101 @ 172 POUNDS PER 100 SQUARE FEET AND SEALED WITH SOCONY ASPHALT 105 @ 31 POUNDS PER 100 SQUARE FEET. This was laid for 2 miles in May 1937. Average cost per 100 square feet Rs. 20/12/10.

PRESENT CONDITION.—Good.

EXPERIMENT WITH CUTBACK OF BITUMEN.

COMMENCING 27M. OF.

The mile was divided into 2 experimental lengths.

On the first part, after thoroughly clearing the surface, Socofix at 4 gallons per 100 square feet was applied over which 4-5 cubic feet of $\frac{3}{4}$ -inch to $\frac{1}{2}$ -inch stone chips were spread. This was then rolled with a 10-ton stream roller.

The second part was treated with the application of Socofix at 6 gallons per 100 square feet approximately on the cleaned road surface and chips spread at 5 cubic feet per 100 square feet. A drag-broom was then drawn backwards and forwards over the length of road by a motor lorry, until the stone chips were coated and the unevenness of the surface was automatically corrected. Smaller gaps were filled with $\frac{3}{8}$ -inch to $\frac{1}{8}$ -inch stone chips precoated with Socofix. About 2 cubic feet of sand per 100 square feet were spread after an interval of about 18 hours and the road thoroughly rolled with a 10-ton road roller. The road was opened to traffic after final rolling.

COMMENCING 28M. OF.

2-INCH GROUT WITH HOTFIX 30/40 @ 176 POUNDS PER 100 SQUARE FEET AND SEALED WITH HOTFIX 80/100 AT 35 POUNDS PER 100 SQUARE FEET. This was laid for one mile in May 1937. Cost per 100 square feet Rs. 21/9/3.

PRESENT CONDITION.—Good.

COMMENCING 30M. OF.

(i) 2-INCH GROUT WITH TRINIPHALT AT 172 POUNDS PER 100 SQUARE FEET AND SEALED WITH SPRAYPHALT AT 35 POUNDS PER 100 SQUARE FEET. This was laid for 2 miles in March 1938. Average cost per 100 square feet Rs. 21/4/4.

PRESENT CONDITION.—Good.

COMMENCING 32M. OF.

(i) 2-INCH GROUT WITH PITCH AND TAR (2:1) @ 216 POUNDS PER 100 SQUARE FEET AND SEALED WITH SPRAMEX @ 37 POUNDS PER 100 SQUARE FEET. This was laid for 3 furlongs 613 feet in May 1937. Cost per 100 square feet Rs. 21/0/4.

(ii) 2-INCH GROUT WITH PITCH AND TAR (2:1) @ 253 POUNDS PER 100 SQUARE FEET AND SEALED WITH SPRAMEX AT 32 POUNDS PER 100 SQUARE FEET. This was laid for 4 furlongs 47 feet in May 1937. Cost per 100 square feet Rs. 19/1/11.

(iii) 2-INCH GROUT WITH PITCH AND TAR (2:1) AT 253 POUNDS PER 100 SQUARE FEET AND SEALED WITH SPRAMEX @ 85 POUNDS PER 100 SQUARE FEET. This was laid for 5 furlongs in 1937-38. Cost per 100 square feet Rs. 21/5/-.

(iv) 2-INCH GROUT WITH PITCH AND TAR (2:1) @ 353 POUNDS PER 100 SQUARE FEET AND SEALED WITH SOCONY ASPHALT 105 @ 59 POUNDS PER 100 SQUARE FEET. This was laid for 3 furlongs in 1937-38. Cost per 100 square feet Rs. 22/12/9.

PRESENT CONDITION OF THE ABOVE LENGTH—Good.

EXPERIMENT WITH CUTBACK OF BITUMEN.

COMMENCING 34M. OF.

This Mile was a new water-bound macadam, shaded with trees and subjected to tree drips. The experiment was for low cost road surfacing. Socony Liquid Asphalt No 2 and sand were used on this mile.

TREATMENT.—The road was cleaned and Socony Liquid Asphalt No. 2 was applied by means of a perforated kerosene oil tin. The rates of application varied from 2-3 gallons per 100 square feet and the time allowed for penetration varied from 12-48 hours. This Mile has been maintained by patch painting with Liquid Asphalt No. 2 in conjunction with sand only.

PRESENT CONDITION.—Fair.

COMMENCING 34M. 6F. 420 FEET

2-INCH GROUT WITH BLENDED PITCH AND TAR AT 296 POUNDS PER 100 SQUARE FEET AND SEALED WITH SPRAMEX AT 83 POUNDS PER 100 SQUARE FEET. This was laid on one furlong 240 feet in April 1938. Cost per 100 square feet Rs. 26/12/.

PRESENT CONDITION.—Good.

COMMENCING 35M. OF

(i) 2-INCH GROUT WITH MEXPHALT AT 167 POUNDS PER 100 SQUARE FEET AND SEALED WITH SPRAMEX AT 56 POUNDS PER 100 SQUARE FEET.—This was laid for 7 furlongs in March 1938. Cost per 100 square feet Rs. 22/5/6.

(ii) 2-INCH GROUT WITH MEXPHALT AT 167 POUNDS PER 100 SQUARE FEET AND SEALED WITH SOCONY ASPHALT 105 AT 56.70 POUNDS PER 100 SQUARE FEET. This was laid in one furlong in March 1938. Cost Rs. 22/6/.

(iii) 2-INCH GROUT WITH PITCH AND TAR (3: 2) AT 235 POUNDS PER 100 SQUARE FEET AND SEALED WITH SPRAMEX AT 55 POUNDS PER 100 SQUARE FEET. This was laid for 7 furlongs 330 feet in April 1938. Cost per 100 square feet Rs. 24/7/6.

(iv) 2-INCH GROUT WITH BLENDED PITCH AND TAR AT 225 POUNDS PER 100 SQUARE FEET AND SEALED WITH SPRAMEX AT 55 POUNDS PER 100 SQUARE FEET. This was laid for 330 feet in April 1938. Cost per 100 square feet. Rs. 24/7/6.

PRESENT CONDITION.—Good.

At 12.55 p.m., the delegates returned to their lodgings.

The delegates re-assembled near Band-stand at Eden Gardens at 2.30 p.m. and proceeded in taxis to visit the Test Track at Alipore established by the Government of India on the recommendation of the Roads Congress and designed and elected under the direction of Mr. E. F. G. Gilmore, Director, Industrial Research Bureau, Indian Stores

Department. Mr. K. G. Mitchell, C.I.E., Consulting Engineer to the Government of India (Roads), in the course of a short address, explained to the engineers assembled the utility of the Test Track which was to find out in a very short time the most suitable and economical specification obtainable, with the use of different classes of stone metal and different binders, to stand a given amount and intensity of bullock-cart traffic. The Test Track would thus save much time and money which is now being spent on scattered experiments all over the country. Mr. Gilmore briefly explained the mechanism of the test track.

The Diamond Harbour road was next inspected. The particulars of experiments carried out on this road are as follows:—

COMMENCING 5M. 2½F. (TRAMWAY TERMINUS.)

2-INCH PREMIX CARPET—BASE COAT WITH HIGH VISCOSITY ROAD TAR AT 4.5 POUNDS PER CUBIC FOOT OF STONE METAL AND STONE CHIPS AND TOP COAT WITH PREMIXED CHIPS OF TAR NO. 3 AT 4 POUNDS TO 6 POUNDS PER CUBIC FOOT OF STONE CHIPS AND SEALED WITH TAR NO. 3 AT 45 POUNDS PER 100 SQUARE FEET.

This was laid in 1½ furlongs in May 1935. The cost of the work per 100 square feet is Rs. 20/-. It was repainted with one coat of Tar No. 3 at 33 pounds per 100 square feet in May 1937.

PRESENT CONDITION.—Good.

(2 coats of painting with Trinidad Asphalt at 112 pounds per 100 square feet were originally applied on a newly sectioned road in December 1931. This specification failed to stand up to the traffic and was replaced by 2-inch premix carpet as noted above.)

COMMENCING 5M. 4F.

2-INCH PREMIX CARPET—BASE COAT WITH HIGH VISCOSITY ROAD TAR AT 4.5 POUNDS PER CUBIC FOOT OF STONE METAL AND STONE CHIPS TOP COAT WITH TAR NO. 3 @ 4 POUNDS TO 6 POUNDS PER CUBIC FOOT OF STONE CHIPS AND SEALED WITH SOCONY ASPHALT 105 AT 45 POUNDS PER 100 SQUARE FEET.

This was laid in 4 furlongs in May 1935. The cost of the work per 100 square feet is Rs. 20/-.

PRESENT CONDITION.—Good.

Previously this length had been resectioned and painted with 2 coats of Trinidad Asphalt in 1931.

COMMENCING 6M. 0F.

(i) 2-INCH PREMIX CARPET—BASE COAT WITH HIGH VISCOSITY ROAD TAR AT 4.5 POUNDS PER CUBIC FOOT OF STONE METAL AND STONE CHIPS, TOP COAT WITH PREMIXED CHIPS OF TAR NO. 3 AT 4 POUNDS TO 6 POUNDS PER CUBIC FOOT OF STONE CHIPS AND SEALED WITH HIGH VISCOSITY ROAD TAR @ 45 POUNDS PER 100 SQUARE FEET.

This was laid for 280 feet in May 1935. The cost of the work per 100 square feet is Rs. 20/-. Repainted with one coat of Tar No. 3 at 33 pounds per 100 square feet in May 1937.

PRESENT CONDITION.—Good.

This length had been previously resectioned and painted with 2 coats of Trinidad Asphalt in December 1931.

(ii) 2-INCH PREMIX CARPET—BASE COAT WITH HIGH VISCOSITY ROAD TAR AT 4.5 POUNDS PER CUBIC FOOT OF STONE METAL AND STONE CHIPS, TOP COAT WITH PREMIXED CHIPS OF TAR No. 3 AT 4 POUNDS TO 6 POUNDS PER CUBIC FOOT OF STONE CHIPS AND SEALED WITH TAR No. 3 AT 45 POUNDS PER 100 SQUARE FEET.

This was laid for 4 furlongs 380 feet in May 1935. The cost of the work per 100 square feet is Rs. 20/-.

It was repainted with one coat of Tar No. 3 at 33 pounds per 100 square feet (except the 5th furlong) in May 1937.

PRESENT CONDITION.—Good.

The road had been treated in 1931 similar to the previous length.

(iii) 2-INCH PREMIX CARPET—BASE COAT WITH HIGH VISCOSITY ROAD TAR AT 4.5 POUNDS PER CUBIC FOOT OF STONE METAL AND STONE CHIPS, TOP COAT WITH PREMIXED CHIPS OF TAR No. 3 AT 4 POUNDS TO 6 POUNDS PER CUBIC FOOT OF STONE CHIPS AND SEALED WITH SOCONY ASPHALT 105 AT 45 POUNDS PER 100 SQUARE FEET.

This was laid for 510 feet in May 1935. The cost of the work per 100 square feet is Rs. 20/-.

PRESENT CONDITION.—Good.

Treated in 1931 similarly as the previous length.

COMMENCING 6M. 5F. 510 FEET:

2-INCH PREMIX CARPET WITH SOCONY ASPHALT 101 AND SOCOSOL (1: 1/16) AT 4 POUNDS PER CUBIC FOOT OF AGGREGATE AND SEALED WITH SOCONY ASPHALT 105 AT 45 POUNDS PER 100 SQUARE FEET.—This was laid for 2 furlongs 150 feet in May 1935. The cost of the work per 100 square feet is Rs. 20/-.

PRESENT CONDITION.—There are signs of slight wear in places. Treated in 1931 similarly as the previous length.

COMMENCING 7M. 0F.

(i) (WEST HALF) (A) 2-INCH PREMIX CARPET—BASE COAT WITH HIGH VISCOSITY ROAD TAR AT 4.5 POUNDS PER CUBIC FOOT OF STONE METAL AND STONE CHIPS, TOP COAT WITH PREMIXED CHIPS OF TAR No. 3 AT 4 POUNDS TO 6 POUNDS PER CUBIC FOOT OF STONE CHIPS AND SEALED WITH SOCONY ASPHALT 105 AT 45 POUNDS PER 100 SQUARE FEET.

(EAST HALF) (B) 2-INCH PREMIX CARPET WITH LIQUAPHALT AT 3.5 POUNDS PER CUBIC FOOT OF AGGREGATE AND SEALED WITH SOCONY ASPHALT 105 AT 45 POUNDS PER 100 SQUARE FEET.

The works (marked A and B) were done on one furlong of the road in May 1935.

The cost of these works per 100 square feet is Rs. 20/-.

PRESENT CONDITION.—Good.

(ii) 2-INCH SHELLCRETE WITH MEXPHALT AND SHELLMAX (2: 1) AT 144 POUNDS PER 100 SQUARE FEET.—Stone metal ($1\frac{1}{2}$ inch graded) and sand (Proportion 2: 1) Hot Bitumen at 35 pounds per cubic foot of Stone metal (aggregate) and at 8 pounds per cubic foot of sand).

This was laid for 7 furlongs in February 1935.

The cost of the work per 100 square feet is Rs. 17/2/-

A seal coat with Shellmac at 22 pounds per 100 square feet and sand was given in February 1936.

The cost of the seal per 100 square feet is Rs. 1/7/7

The intensity of traffic in 24 hours for 20 feet width of road is 932.59 tons as per census taken in February 1938 page 84.

PRESENT CONDITION.—There are signs of wear. The whole is to be sealed and chipped before next rains. (Painting 2 coats with Spramex at $84\frac{1}{2}$ pounds per 100 square feet was done, in December 1931).

The surface failed and was replaced.

Previously, the road had been resectioned in 1931 and painted with 2 coats of Spramex at $84\frac{1}{3}$ pounds per 100 square feet.

COMMENCING 8M. 1F. 182 FEET.

(i) 2-INCH TAR-CRETE WITH HIGH VISCOSITY ROAD TAR @ 162 POUNDS PER 100 SQUARE FEET.—This was laid in 330 feet in May 1937: The cost of the work per 100 square feet is Rs 20/-.

This was sealed with Tar No. 3 at 22 pounds per 100 square feet and sanded in June 1938.

The cost of seal per 100 square feet is Rs. 1/7/-.

PRESENT CONDITION.—Good.

(ii) 2-INCH SHELL-CRETE WITH MEXPHALT AND SHELL-MAC (1: 1/16) AT 144 POUNDS PER 100 SQUARE FEET.

This was laid in 6 furlongs 148 feet in April 1936.

The cost of the work per 100 square feet is Rs 18/-.

This was sealed with Colas at 12 pounds per 100 square feet and sanded in May 1937.

The cost of seal per 100 square feet is Rs. 1/6/11.

PRESENT CONDITION—Good except in 7th and 8th furlongs where several pot-holes have formed.

The road was previously resectioned and painted with 2 coats of Spramex in 1931.

COMMENCING 9M. OF.

(i) 2-INCH GROUT WITH MEXPHALT AT 132 POUNDS TO 154 POUNDS PER 100 SQUARE FEET AND SEALED WITH MEXPHALT AT 45 POUNDS PER 100 SQUARE FEET.

This was laid for 3 furlongs in July 1934. The cost of work per 100 square feet is Rs. 22/-.

Repainted with one coat of Spramex at 22 pounds per 100 square feet in June 1937.

PRESENT CONDITION—A few pot-holes have appeared in places.

(ii) 2-INCH GROUT WITH MEXPHALT AT 154 POUNDS PER 100 SQUARE FEET AND SEALED WITH SPRAMEX AT 45 POUNDS PER 100 SQUARE FEET.

This was laid for 3 furlongs in July 1934. The cost of the work per 100 square feet is Rs. 22/-. Repainted with one coat of Spramex at 22 pounds per 100 square feet in January 1937.

PRESENT CONDITION.—Good.

(iii) 2-INCH GROUT WITH MEXPHALT AT 176 POUNDS PER 100 SQUARE FEET AND SEALED WITH SPRAMEX AT 45 POUNDS PER 100 SQUARE FEET.

This was laid for 2 furlongs in July 1934. The cost of the work per 100 square feet is Rs. 24/-. Repainted with one coat of Spramex at 22 pounds per 100 square feet in February 1938.

PRESENT CONDITION.—Good.

This length was originally painted with Bitumuls after the road was resectioned in 1931.

COMMENCING 10M. OF.

(i) 1-INCH COLFIX CARPET AT 134 POUNDS PER 100 SQUARE FEET AND SEALED WITH SOCONY ASPHALT 105 AT 45 POUNDS PER 100 SQUARE FEET.

This was laid for 2 furlongs in June 1934. The cost of the work per 100 square feet is Rs. 19/3/-.

PRESENT CONDITION.—Surface has again failed and is now proposed to be covered with 2-inch bitumen grouting.

(ii) PAINTING 2 COATS WITH SOCONY ASPHALT NO. 105 AT 105 POUNDS PER 100 SQUARE FEET AND AT 91 POUNDS PER 100 SQUARE FEET.

This was laid in one furlong in July 1935. The cost of the work per 100 square feet is Rs. 11/2/-. Repainted with one coat Socony Asphalt No. 105 at 22 pounds per 100 square feet in 1937.

PRESENT CONDITION.—There are signs of wear.

In 1931 after resectioning the road 2 coats of Colfix at 89 pounds per 100 square feet were applied in May 1931.

COMMENCING 10M. 3F.

1-INCH CARPET WITH HIGH VISCOSITY ROAD TAR AT 55 POUNDS PER 100 SQUARE FEET AND SEALED WITH TAR No. 3 AT 45 POUNDS PER 100 SQUARE FEET.

This was laid on 2 furlongs in June 1934. The cost of the work per 100 square feet is Rs. 17/1/-.

PRESENT CONDITION.—Surface has again failed and it is now proposed to replace it with a 2-inch grout with Socony Asphalt 101 and 105.

Painting 2 coats with Colfix at 89 pounds per 100 square feet was originally laid in May 1931. The surface failed and was replaced by 1-inch Carpet with High Viscosity Road-Tar as noted above.

The delegates then proceeded to visit the Government Test House at Alipore where, amongst many things of great interest, the following were inspected :—

- (a) Exhibits of road metal samples from all over India.
- (b) Attrition and abrasion testing machines.
- (c) Testing of ductility, volatility and penetration of bitumen,
- (d) Testing of viscosity of road-tar, distillation of road-tar, softening point of bitumen, pitch and other road surfacing materials,
- (e) Physical tests on cement, surkhi, lime, etc.,
- (f) Testing of vegetable oils as lubricants and fuels,
- and (g) Viscosity and flash-points of oils.

The delegates returned to their lodgings at about 6 p.m.

Tuesday, February 14, 1939.

The delegates assembled at 7 a.m. near Eden Gardens and proceeded in taxis to the Kunti bridge, inspecting the Grand Trunk Road on the way.

One of the earliest attempts at grouting outside Calcutta was made in 1925-26 on the Grand Trunk Road, Howrah which was cut up by the increasingly heavy lorry traffic and ordinary repairs failed to keep the road in order. The dust nuisance was also very great.

A traffic census taken on this road is on page 85. Pitch and tar in the proportion of 2:1 and at 15 pounds per square yard were laid at a cost of Re. 1/- per square yard excluding cost of stone metal, and though these miles were laid about 13 years back, there has been no occasion to replace the original surface and only occasional repairs were done by pitching and painting with the same materials. In some places where the surface developed corrugations, instead of disturbing the surface and rectifying the defects at heavy cost, it was overlaid with $1\frac{1}{2}$ -inch pitch and tar grouting, adding to the strength of the road, and the defects have disappeared. Portions of the road were picked up about 5 years back to see how the work was behaving and the matrix at the bottom of the 2-inch layer retained all the strength and life. These miles prove the undoubted success of the tar and pitch grouting with a comparatively small amount of matrix.

4TH MILE, $\frac{1}{2}$ OF THE 3RD FURLONG TO 6TH MILE, 6TH FURLONG,
DONE IN 1925-26, 1926-27.

2-INCH THICK TAR MACADAM WITH PITCH AND TAR GROUTING
IN THE PROPORTION OF 2: 1 WITH 15 POUNDS OF MIXTURE PER
SQUARE YARD WITH STONE CHIPS AND SAND TOPPING.

8TH MILE.

2-INCH BITUMAL GROUTING WITH SEAL COAT WAS LAID IN
1932-33. It is being painted with Bitumal Emulsion from time to time.
The surface is wearing well but slight corrugation has formed.

9TH-12TH MILE.

BITUMAL PAINTING. The surface is wearing well. The repainting
is required to be done in alternate years. In mile 9th to 11th—
the surface at either edges up to 4 feet in width usually breaks and
peels off—specially in rainy season, due to bullock-cart traffic.

13TH MILE.

MEXPHALT GROUTING was done in 1932-33. Repainting with
Spramex is being done in every third year. Surface is wavy, pot-holes
frequently appear, the bitumen creeps in hot season.

14TH MILE.

PITCH AND TAR GROUTING was done in 1931-32 and 1932-33.
Seal coat was done with Colas. Subsequent repainting is being done
with Colas in every alternate year.

Surface.—Central portion in good condition, edges upto 5 feet width
on either sides break and peel-off like scales, due to bullock-cart traffic.

15TH & 16TH MILE.

PITCH AND TAR GROUTING was laid in 1932-33 with Spramex,
seal coat and subsequent repainting is being done with Spramex.
Repainting necessary in every 3rd or 4th year.

Surface—bitumen creeps—15th mile is slightly wavy, patches formed, 16th mile in good condition.

17TH MILE.

HIGH VISCOSITY TAR AND PITCH GROUTING WITH SEAL COAT OF TAR NO. 2 LAID IN 1932-33. Repainting necessary every third year. Surface even, but peeling off started and patches formed.

18TH—20TH MILE.

2-INCH PITCH AND TAR GROUTING SEAL COATED WITH SPRAY-MEX. Repainting necessary every 3rd or 4th year. Surface good. Pot-holes appeared in 18th mile, the surface in all other miles is good.

19TH MILE NEW.

PITCH AND TAR GROUTING WITH SEAL COAT LAID IN 1931-32. Repainting done with Colas every fourth year.

Surface—in good state.

20TH MILE.

PITCH AND TAR GROUTING WITH SEAL COAT LAID IN 1931-32. Resectioned in 1935-36 with 2-inch grouting with Socony Asphalt (half of 19th and half of 20th mile). Subsequent repainting done with Colas in every 3rd year. Surface is in very good state. Last 2 quarters of 20th mile have Colas painting over Tar and Pitch grouting

Surface—good, no signs of decay.

21ST MILE.

PITCH AND TAR GROUTING WITH SEAL COAT LAID IN 1931-32. Subsequent repainting being done with Socony No. 6 in every 3rd year.

Surface—good.

22ND & 23RD MILE.

SPRAYPHALT 1st COAT IN 1934-35 AND 2nd COAT IN 1935-36. Surface in 22nd mile slightly uneven, a few patches formed. 23rd mile—uneven, a few patches formed. Repainting has become necessary now.

24TH MILE.

TRINIPHALT 1st COAT IN 1934-35, 2nd COAT IN 1935-36. Repainting in 1937-38. Surface—appears wavy.

25TH TO 31ST MILES.

PAINTED WITH COLFIX IN 1930-31. Resectioning done in 1934-36 except in 27th mile. Subsequent repainting being done with Socony 105 except half of 28th mile which is being done with Road Tar. Repainting

necessary every alternate year. Surface good in all places except 28th mile which is patchy.

32ND, & 33RD MILES.

PAINTED WITH COLFIX IN 1930-31. Subsequent repainting being done with Spramex. Repainting necessary every alternate year.

34TH MILE.

PAINTED WITH BITUMAL IN 1932-33. Subsequent repainting being done with Spramex. Repainting necessary every alternate year. Surface fairly good. Patches formed in first two quarters.

KUNTI BRIDGE

Site.—The bridge is located on the 34th mile of the Grand Trunk Road on the River Kunti, which is a branch of the Damodar, taking off from the parent stream near Salimabad in the district of Burdwan. Proceeding southwards into the Hooghly District, the stream changes its name from place to place. In its course through the districts of Burdwan and Hooghly, it is joined by several other streams.

General Design.—The Bridge will be a reinforced one of the balanced cantilever type and has been designed to carry 9 British Standard unit loads with proper allowances for impact. The road will be 18 feet wide with a 2 feet 6 inches wide foot-path on either side.

Spans and Beams.—The bridge will have 3 main spans and 2 approach spans. The central main span will be 67 feet and the end span 52 feet between supports. The approach spans will be 12 feet long.

The central span beam will be 67 feet between supports with a 14 feet long cantilever at each end. The end beams will be 38 feet long, one end of which will rest on the abutments of the old bridge which is being replaced and the other end will rest on the cantilever end of the central span.

The over-all length of the bridge will be 205 feet and the width will be 24 feet.

Four expansion joints have been provided in the whole length of the Bridge.

Superstructure.—There will be 3 main girders of varying depth, at 9 feet centres, one at each end of the main road-way and one at the centre. The cross beams will be placed at about 9 feet centres. The foot-paths will be cantilevered out from the top of the main beams.

The decking slab will be 7 inches thick with a 4-inch layer of weak concrete over it and finished with a 2-inch wearing course. A 1/4-inch thick layer of asphalt will be laid over the decking slab in order to make it water-proof.

Piers.—The pier will be a hollow concrete one with suitable reinforcements. The individual walls will be $7\frac{1}{2}$ inches thick with vertical and lateral reinforcements. The two longitudinal walls will be bent at the ends to form cut-waters and will be joined and stiffened by 8 cross walls at 3 feet centres. The over-all width of the piers will be 3 feet- $7\frac{1}{2}$ inches. The top of the hollow pier will be covered by a 2 feet thick Reinforced concrete capping slab on which will rest the bearings supporting the bridge.

Bearings.—The bearings will be of German manufacture and made of cast steel. Both Rocker and Roller bearings have been provided. Both the extreme ends of the side spans will rest on rollers. The capacity of each of the bearings supporting the central span and cantilever is 150 tons whereas that of the end-span bearings is 50 tons.

Foundations.—The foundation of the 2 Reinforced Concrete piers will consist of 12 Reinforced Concrete piles under each pier. The piles will be 13 inches diameter octagonal ones with 8 Nos. 5/8 inch vertical bars and 3/8 inch helical reinforcements at 2 inches pitch in the central portions and $1\frac{1}{2}$ inches pitch at the two ends. The piles will be placed in 3 rows, the central piles will be driven vertical, whereas the end ones will be driven with an inclination of 1 in 20. After driving, the concrete in the top end of the pile will be stripped off and the reinforcing rods will be splayed out and embedded in the 3 feet capping slab to be constructed over the piles.

Materials (a) Steel.—High tensile steel bars will be used in the beams and structural slabs in the main bridge and mild steel bars will be used in other places.

(b) Concrete.—Structural concrete of crushing strength of not less than 3,500 pounds per square inch will be used in all important parts of the bridge. The aggregate of such concrete will be graded so as to conform to the Fuller Curve. The wearing surface of the road-way will be made of concrete of not less than 4,000 pounds crushing strength.

Preliminary works.—As the new bridge was to be erected on the existing bridge site, a temporary diversion for keeping the road open to traffic during the period of re-construction became necessary. This was done by shifting the existing bridge bodily sideways and placing it on temporary piers and abutments built for the purpose.

Shifting of old bridge.—Two new brick piers were constructed similar and adjacent to and also in line and level with the old ones. To shift the central span, on to the top of both the adjacent piers, skidways 2 feet wide and continuous over the length to be traversed by the span, were prepared. The skidway consisted of 2 feet wide plate fixed to the pier by counter-sunk bolts with their top surfaces greased. In order to resist distortion during shifting, the steel structure was strengthened by connecting the top and bottom booms by a system of *Sal balla* and mild steel angle ties and struts.

To change the old bearings for new ones which became necessary for the purpose of shifting the spans, the ends of the two girders on each pier were lifted simultaneously by means of two hydraulic jacks of 50 tons capacity and the bearings were replaced.

The actual shifting was done by pulling slowly the ends of the central span with two crab winches of 50 tons capacity. One-inch wire ropes were used and the pull was applied by the winches through a system of pulleys. The end spans were then shifted in a similar manner. The bridge had to be kept closed against traffic for 34 hours in order to shift the spans and to make short diversions at either end of the bridge. The actual shifting and the works in connection therewith took only 28 hours.

Test piles.—In order to ascertain roughly the length of pile required in order to get the specified set, it was decided to drive a test pile 50 feet long. The test pile went without any trouble up to a depth of 10 feet. At this point the penetration per blow became suddenly very small and the pile began to go out of the vertical. When the shoe reached a depth of about 15 feet from the ground, the pile almost refused to go further and became definitely bent, with hair cracks in many places. As it was apprehended that the pile had met with some obstacle, trenches were dug in places and it was found that the pile had met with a mass of masonry block. The extent of the masonry block was roughly determined by probing at different places. A cofferdam was then built around the place and the earth was removed till the surface of the masonry block was exposed. The block was then removed at first by manual labour and subsequently by blasting. From the nature of the masonry block, its size, position and also the presence and position of certain piles under it, it is surmised that there are the remains of the piers of an old bridge, which probably collapsed through scouring.

Pile driving in the south bank.—After removing the masonry in the south bank, the trench was filled up and the actual pile driving was started. No difficulty was experienced this time but at a depth of about 38 feet, the driving became hard and the penetration per blow became very small leading to the supposition that the piles met with some obstruction at that level. After going 3 or 4 feet deeper, the piles sank more easily. The probability is that the piles met with a bed of sand at that level. The average depth of piles driven is about 47 feet with an average time of 18 hours for each pile.

From Kunti Bridge, the delegates proceeded to the Dunlop Rubber Factory where the management showed them round the various stages of the manufacture of pneumatic tyres for cycles, motor vehicles and bullock carts. The visit was highly interesting and was much appreciated. The delegates were then treated to light refreshments and the acting Managing Director in welcoming the delegates spoke of the progress made by the factory during its short existence and mentioned that the factory had provided employment to a large number of men and was using large quantities of raw rubber grown in India and Burma. The President of the Congress thanked the management on behalf of the delegates.

The delegates returned to their lodgings *via* the Willingdon Bridge at 12 noon.

In the afternoon, the delegates assembled at the Institution of Engineers, (India), 8 Gokhale Road, near Presidency General Hospital, behind the Calcutta Club, at 3 p.m. when after the Presidential Address* the Hon'ble Maharaja Srischandra Nandy, Minister for Communications and Works delivered his speech† and formally opened the Congress Session. A group photograph of the delegates with the Hon'ble Maharaja was then taken.

At 4-45 p. m., the Council of the Indian Road Congress were "At Home" to the delegates and certain distinguished guests.

In the evening Dr. A. N. Puri, Soil Physicist, Irrigation Research Institute, Lahore, gave a short discourse on simple experimental methods of finding out the amounts of certain salts (*e. g.* Sodium sulphate) in soil samples and illustrated these by experiments.

The delegates were then shown films on "Road Construction in Bengal" by the Bengal Publicity Department, on "Soil Stabilization Method in America" by Mr. C. D. N. Meares and on "The Cairo-Alexandria Desert Road Construction" by Messrs. The Burmah-Shell Company, after which the meeting dispersed.

Wednesday, February 15-1939.

The delegates assembled at 7-45 A. M. at Eden Gardens and in two batches, visited in turn the Maidan Roads‡ and a demonstration of "Franki Pile" driving and the New Howrah Bridge construction, through the courtesy of the commissioners for that Bridge. The delegates were presented with a nice little brochure containing engineering details of this colossal bridge of the cantilever type, similar in principle to the Quebec Bridge. The leading dimensions of the bridge as mentioned in the brochure will be as follows :—

- (a) The total roadway width is 71 feet, comprising 9 feet bullock-cart tracks close to each curb, two tramway tracks in the centre of the roadway and two fast-traffic lanes in each direction between the bullock-cart tracks and the tramway.
- (b) Two footways are provided each 15 feet clear width on either side and railed off from the roadway.
- (c) The clearance of the roadway beneath the main structure is 19 feet.

* The Presidential Address appears on pages 5 to 10.

† The Hon'ble Maharaja's speech appears on pages 10 to 12.

‡ Specifications of these roads appear on pages 74 to 80.

- (d) The river clearance under the floor of the bridge is 29 feet minimum at highest water level, giving about 35 feet clearance ordinarily.
- (e) The length of the main span centre to centre of main piers is 1,500 feet. The total overall length of the bridge is 2,150 feet made up of two shore arms, each 325 feet long, two cantilever arms, each 468 feet long and the suspended span, 564 feet long.
- (f) The overall height of the towers above ground level is 300 feet approximately.
- (g) The main foundation is 181 feet 6 inches long and 81 feet 6 inches wide.
- (h) The anchorage foundations consist of two 54 feet by 27 feet monoliths, connected at the top by a tie-beam to make a unit 104 feet by 54 feet.

CALCUTTA MAIDAN ROADS.

The specifications to which these roads have been constructed are as follows :—

AT PEEL STATUE JUNCTION OF STRAND ROAD AND EDEN GARDEN ROAD.

(1) 4½-INCH THICK TARCRETE PAVEMENT WITH SIMILAR HIGH VISCOSITY ROAD TAR (MACHINE MIXED), Laid on the east flank of Strand Road (area 94 square yards) in February 1938. Matrix used at the rate of 4.24 pounds per cubic foot of aggregate (2 stone metal and 1 sand). Cost is Rs. 42/10/- per 100 square feet.

CONDITION—Though the Matrix has worked up and the surface withstood the iron-tyred cart traffic satisfactorily uptil now, it is too early to pass any opinion.

(2) STONE SETT PAVEMENT LAID FLAT over an area of 30 feet by 14 feet in the east flank of Strand Road laid about 10 years ago. Practically no repairs done yet.

CONDITION—Fair

(3) CEMENT CONCRETE PAVEMENT no repairs done yet.

CONDITION—Very bad

(4) CEMENT CONCRETE BRIQUETTE no repairs done yet.

CONDITION—Very bad

(5) 1-INCH ROCK ASPHALT PAVEMENT (over freshly consolidated Water-bound macadam) laid on the east flank of Strand Road up to Calcutta Water Gate (North side) in December 1938.

Matrix used—Rock Asphalt mixed with $\frac{1}{2}$ -inch size stone chips (proportion 2 : 1) laid over a coat of Colfix priming and finished with fine rock Asphalt with admixture of cement. The cost was Rs. 26/4/- per 100 square feet.

(6) 3-INCH TARCRETE PAVEMENT WITH SHALIMAR HIGH VISCOSITY ROAD TAR (Mixed in hand-made drums). Laid on east flank of Strand Road opposite the Calcutta Water Gate laid in 1935-36. Matrix used at the rate of 5 pounds per cubic foot of aggregate (2 metal : 1 sand). No seal coat. Cost Rs. 22/6/- per 100 square feet.

PRESENT CONDITION.—Good. The area treated is subjected to heavy traffic. (71.25 tons per foot width in 24 hours). The matrix has almost worked up to an effective seal and the pavement has stood well under the wheels of heavy cart traffic.

NAPIER ROAD BIFURCATION.

(7) 3-INCH PREMIXED TAR CARPETTING SEAL-COATED WITH ROAD TAR No. 3—laid in 1934-35 at 3.5 pounds of Road Tar No. 3 per cubic foot of aggregate (2 inches to $1\frac{1}{2}$ inches metal 25 per cent, $1\frac{1}{2}$ inches to 1 inch metal 50 per cent and 1 inch to $\frac{3}{4}$ inch metal 25 per cent for base coat, and $\frac{3}{4}$ inch to $\frac{1}{2}$ inch chips 50 per cent and $\frac{1}{2}$ inch to $\frac{1}{4}$ inch chips 50 per cent for the top coat). Cost Rs. 26/13/- per 100 square feet.

PRESENT CONDITION.—The seal coat wore out and pot-holes developed in several places though the surface was attended to by periodical patch repairs. Re-sealed with Tar No. 3A premixed stone chips in December 1938.

WEST FLANK STRAND ROAD UP-TO LAMP POST 43.

(8) BITUMUL H. X. PAINTING 2 COATS (cold emulsion),—laid on freshly consolidated water-bound Macadam in December 1938.

Matrix used at 5.8 gallons per 100 square feet. Stone chips about 7 cubic feet per 100 square feet. Cost Rs. 10/3/0 per 100 square feet.

CONDITION.—It is too early to pass any opinion.

(9) LIQUID ASPHALT AND SOCOFIX TREATMENT on freshly consolidated water-bound macadam laid in June 1936 on the west flank of Strand Road from Lamp Post 43 to Lamp Post 25 (opposite the Peel Statue). Cost is Rs. 8/-/6 per 100 square feet.

LAMP POST 43 TO 39.

(a) 4th stretch,—BASE COAT WITH LIQUID ASPHALT No. 2, cold application on dry surface at 2 gallons per 100 square feet. TOP COAT WITH SOCOFIX, cold applications at 3 gallons per 100 square feet.

LAMP POST 39 TO 35.

(b) 3rd stretch,—BASE COAT LIQUID ASPHALT No. 1, cold application on dry surface at 4 gallons per 100 square feet. TOP COAT SOCOFIX cold application at 3 gallons per 100 square feet.

LAMP POST 35 TO 29.

(c) 2nd stretch,—BASE COAT LIQUID ASPHALT No. 1, hot application on damp surface at 4 gallons per 100 square feet. TOP COAT SOCONY ASPHALT No. 101, hot application at 3 gallons per 100 square feet.

LAMP POST 29 TO 25.

(d) 1st stretch,—BASE COAT—Same as experiment No. (c). TOP COAT SOCOFIX cold application at 3 gallons per 100 square feet.

CONDITION. The treated surface in all the four cases has had to be attended to all along and repairs to the extent of about 1/3rd the cost of outlay have already been carried out. The surface has again been showing signs of disintegration and a few pot-holes have actually developed.

(10) PREMIXED TAR CARPETTING (2½ INCHES TO 3 INCHES THICK) WITH HIGH VISCOSITY ROAD TAR AND TAR No. 3 AND SEALED WITH SOCONY ASPHALT No. 105. Laid on Lawrence Road in January to March 1936. Cost is Rs. 26/13/- per 100 square feet.

BASE AND TOP COATS (i) With High Viscosity Road Tar. Premix at 4 pounds per cubic foot of aggregate (same as experiment No. 7) on the whole width at the start and a strip on the south flank.

(ii) With Tar No. 3 Premix at 3.5 pounds per cubic foot of aggregate on the northern strip. Seal-coat with Socony Asphalt No. 105 at 45 pounds per 100 square feet.

CONDITION.—The surface stood quite well without any attention and further expense until the advent of the last monsoon since when signs of disintegration have appeared on the north flank which is subjected to cart-traffic, and pot-holes actually developed and had to be patched up.

AT RED ROAD AND MAYO ROAD JUNCTION.

(11) 3-inch premixed carpetting with High Viscosity Road Tar (for base coat) and Tar No. 3A (for Top coat.)

Being laid at the junction of four roads, with 5 pounds of matrix per cubic foot of aggregate in January 1939. Has not yet been sealed. Cost not calculated yet.

(12) 2½-INCH PREMIXED CARPETTING WITH ROAD TAR No. 3. Laid on Mayo Road up to Mayo Statue in February-March 1935 and sealed in April 1935. Cost excluding seal coat is Rs. 19/10/- per 100 square feet.

BASE AND TOP COATS.—Matrix used at the rate of 3.5 pounds per cubic foot of aggregate (same proportion of metal as in experiment No. 7).

SEAL COAT.—North half width—Spramex at 44 pounds per 10 square feet. South half width—Spramex with Tar No. 3 at 44 pounds per 100 square feet.

CONDITION.—The surface stood well for about 2 years after which signs of wear appeared on both flanks due to cart-traffic and pot-holes developed. About 14 feet width of road on either flank has since been repainted with Spramex and Tar No. 3A respectively. The condition of central portion, which is not subjected to iron-tyred traffic, is, however quite satisfactory and no attention has to be given since the original laying.

The delegates re-assembled at Eden Gardens at 2 p.m. and proceeded in taxis to inspect the Barrackpore Trunk Road upto Ichapur Bridge. The specifications of treatments carried out on this road are as given below:—

- (1) (a) **STONE SETT PAVEMENT ON 6-INCH LIME CONCRETE BED** laid on the South approach to Talla Bridge up gradient (West half) in 1922.

PRESENT CONDITION.—The surface being eroded and cut through under the wheels of heavy iron-tyred cart-traffic, it has been necessary to relay some length with entirely new setts and some portion with old and new setts in 1937-38. The remaining length also needs attention but, not being very bad, has been left over as a proposal is afoot to raise this approach to the level of the new Barrackpore Bridge under construction.

- (b) **GROUTING AND SEAL COAT WITH PITCH AND TAR** ($2\frac{1}{2}$: 1) at 30 pounds per square yard on the other half width.

CONDITION.—FAIR.

- (2) **6-INCH CONCRETE ROAD REINFORCED WITH B.R.C. FABRIC**—laid on the bridge proper in 1926-27. Surface badly eroded and pot-holes developed in good many places. Covered with stone setts laid flat over sand cushion in 1934-35. No repairs done since.

- (3) **ASPHALT MACADAM (AND REINFORCED TAR MACADAM OVER A PORTION OF THE WEST HALF ONLY)** laid in 1926-27, over the North approach of the Talla Bridge.

CONDITION.—East half width keeping all right—but the west half failed totally under heavily loaded cart traffic and has recently been replaced by tar-crete carpet with High Viscosity Road Tar (Aggregate, 2 metal, 1 sand, matrix at 5 pounds to a cubic foot of aggregate) in November, 1938.

- (4) **VIAMUL MACADAM**—Laid in 1928-29 in 6th furlong of 5th mile.

CONDITION.—Disintegrated badly and pot-holes developed all over; has been repaired with tarmacadam and whole surface repainted with Spramex (at 44 pounds per 100 square feet) in 1937-38.

(5) **TARMACADAM**—at 30 pounds of pitch and Tar ($2\frac{1}{2}$: 1) per square yard laid up to mile stone 7 in 1927-28. Original width—16th feet. Widened to 20 feet (2 feet each side) with 2-inch Tarmacadam over 6-inch consolidated stone metal trap on double layer of Jhama brick soling laid flat (grouting with 18 pounds pitch and Tar 2 : 1) and seal coat at 5 pounds of Spramex per square yard in 1935-36.

CONDITION.—The original area has been repainted with Spramex at 3 pounds per square yard in 1936-37 and is keeping quite all right. In the widened area the depressions at edges are being filled up with Tar (No: 3A) Premix (Aggregate 1 stone metal 1 : 1 stone chips; matrix at 5 pounds per cubic foot of aggregate) over a thin coat of road Tar No. 3A priming.

(6) **TARMACADAM** at 22 pounds of pitch and tar ($2\frac{1}{2}$: 1) laid in 1927-28 upto furlong-stone 5 of mile 8.

Subsequent Treatment.—Same as above.

(7) **TRINIDAD ASPHALT MACADAM**—laid in the 6th furlong of 9th mile in March 1928. 2-inch grouting at 12 pounds and Seal coat at 7 pounds per square yard. Surface repainted every 4th year.

(8) **COLFIX MACADAM** at 1.5 gallons per square yard (cost Rs. 2/12/- per square yard)—laid in 1927-28 in 5th furlong of 14th mile.

CONDITION.—Failed and was replaced by 2-inch Premix carpet with High Viscosity Road Tar at 4 pounds per cubic foot of aggregate (metal and chips) seal coated with Spramex at 44 pounds per 100 square feet in 1934-35. The latter has been keeping well. Surface has been repainted in 1938-39 i.e., after 5 years.

(9) **PREMIX CARPET WITH LIQUAPHALT** per cent 3.5 pounds per cubic foot of aggregate (metal and chips). Laid in 1936-37 over the widened and super-elevated portion of road in 6th and 7th furlongs of 14th mile—seal coated with Spramex at 44 pounds per 100 square feet in 1937-38.

CONDITION.—Quite satisfactory.

BARRACKPORE STATION ROAD.

(10) **MEXPHALT GROUT** (18 pounds per square yard) and Spramex seal coat (4 pounds per square yard)—laid in 1932-33. No repairs have had to be done yet.

GHOSEPARA ROAD.

(11) MEXPHALT GROUT (1st furlong at 133 pounds per 100 square feet 2nd furlong at 146 pounds per 100 square feet sealed with Spramex (at 55 pounds per 100 square feet)—laid in furlong 1 and 2 of 16th mile (1st mile of Ghosepara Road) in April 1934. Surface had to be repainted in 1937-38 (Spramex at 44 pounds per 100 square feet).

16TH MILE 2ND FURLONG.

(12) 2-INCH GROUTING WITH PITCH AND TAR (2:1) at 200 pounds per 100 square feet seal coat with Spramex at 77 pounds per 100 square feet laid in 3rd furlong of 16th mile in February 1934. Surface had to be repainted in 1937-38 (Spramex at 44 pounds).

(13) 2-INCH GROUT WITH PITCH AND TAR SEALED WITH SPRAMEX.

(a) Grout 177 pounds, seal 77 pounds, per 100 square feet—laid in 1935 over the diversion road in 4th furlong of 16th mile. No repairs have had to be done yet.

(b) Grout 177 pounds, seal 77 pounds—laid in 5th to 8th furlong of 16th mile in March 1933.

Furlong 5 to 7 repainted in 1937-38 and Furlongs 8 in 1938-39 (Spramex at 44 pounds).

(14) 2-INCH GROUT WITH PITCH AND TAR SEALED WITH SPRAMEX, GROUT 286 POUNDS, SEAL 39 POUNDS PER 100 SQUARE FEET.—laid in 1st four furlongs of 17th mile in 1933.

F. 1.—Seal coat worn out and surface repainted in 1938-39.

F. 2 and 3—only patch repairs have had to be done.

F. 4—Surface had to be repainted in 1937-38. (Spramex at 44 pounds).

(15) 2-INCH GROUT WITH TEXACO No. 34 SEALED WITH TEXACO No. 96. GROUT 164 POUNDS, SEAL 71 POUNDS PER 100 SQUARE FEET. Laid in last 4 furlongs of 17th mile in June 1933.

CONDITION—Fair. No heavy repairs done yet.

(16) 2-INCH GROUT WITH MEXPHALT SEALED WITH SPRAMEX; GROUT 147 POUNDS, SEAL 54 POUNDS PER 100 —Laid over the entire length of 18th mile in March 1933.

CONDITION—Fair. Seal coat worn out in some places ($\frac{1}{2}$ of F. 4.7 and full of F. 8) and has been repainted with Spramex at 44 pounds in 1938-39.

(17) 2-INCH GROUT WITH PITCH AND TAR (2:1) SEALED WITH SPRAMEX. GROUT 200 POUNDS, SEAL 44 POUNDS PER 100 SQUARE FEET—Laid over the new Ishapore Khal Bridge approaches in 1936-37.

CONDITION—Good. Nothing done yet.

Note : —An index map showing the roads and places visited during the tour is at page 88.

DESCRIPTION OF ICHAPORE KHAL BRIDGE.

1. Province or State	...	Bengal Province.
2. Name & nature of bridge	...	Ichapore Khal Bridge, reinforced concrete continuous beam.
3. Road and milage	...	Ghosepara Road 19th mile 1st furlong
4. Year of construction	...	1936-37.
5. Nature of stream e.g., bed slope, maximum velocity etc.		Tidal Khal.
6. Width and type of road	...	20 feet carriage-way with 2 — 4 feet footpaths on either side cantilevered out.
7. Length between faces of abutments.		122 feet.
8. Number of spans	...	3 Spans.
9. Length of each span	...	Centre span 48 feet, 2 shore spans of 37 feet each.
10. Height above bed level and above foundations level of top of piers.	...	17.17 feet. 19.17 feet.
11. Height above bed level and above foundation level of decking	...	21.17 feet. 23.17 feet.
12. Founded on, (geology)	...	Clay.
13. Type, Section, etc., of foundations		Reinforced concrete Piles 12 inches square, 25 feet to 30 feet long, all driven with top at Reduced Level 0.00.
14. Type, Section, etc., of piers.		Reinforced Concrete Trestle.
15. Type, Section, etc., of abutments.		Brick-in-lime.
16. Type, Section, etc., of arches.		—
17. Type, Section, etc., of decking		6-inch Reinforced Concrete Slab, reinforced with $\frac{1}{2}$ -inch diameter rods at 5-inch centres, both-ways.
18. Total cost of bridge	...	Rs. 33,400/— (approximate).
19. Cost per running foot of road-way.		Rs. 261/-
20. Cost per square foot of road-way		Rs. 13/- (on carriage-way only, not including footpaths).

21. Cost per square foot of openings $\frac{33400}{2000}$ (approximate)—Rs. 16.7
22. Cost per square foot of the elevation area i.e., from the roadway to the bottom of the foundations $\frac{33400}{128 \times 23.67}$ —Rs. 11/-.
23. Annual cost of maintenance, average of recent actuals or budget (give separately cost of painting reduced to annual average per running foot of road-way). Completed only this year.
24. Percentage of maintenance ... Nil
to capital cost.
25. Permissible load ... 12. B.S.A. Units.

On the return journey the delegates visited the Bengal Chemical and Pharmaceutical Works at Panihati. They were shown round the factory by the management. Of particular interest to members was the section where road tar is manufactured. After a very interesting visit, the party was entertained to tea and light refreshments.

The delegates returned to their lodgings at 6 p. m.

TRAFFIC CENSUS IN DISTRICT 24 PARGANAS
FOR ONE DAY OF 24 HOURS
(JESSORE ROAD)

PLACE & TIME OF OBSERVATION		CALCUTTA-JESSORE ROAD 9TH MILE-JUNE 1938			
NATURE OF ROAD AT THE ABOVE PLACE		TARMACADAM			
FULL WIDTH OF ROAD		68'-0"			
METALLED WIDTH OF ROAD		18'-0"			
TYPE OF TRAFFIC	KIND OF TRAFFIC	NUMBER OF EACH KIND	WEIGHT OF EACH KIND	WEIGHT OF EACH TYPE	WT. PER FOOT WIDTH OF METALLED TRACK
AUTO-MOBILE.	Lorry (loaded) each at 3.5 tons	225	787.5 tons		
	Lorry (unloaded) each at 1 ton.	116	116.0 tons		
	Bus each at 2.5 tons	560	1400.0 tons	2411.3 tons	134.0 tons.
	Car each at .75 tons	143	107.0 tons		
	Motor Cycle each at .20 tons	4	.8 tons		
NON-AUTO-MOBILE	4 Wheeled Carts, hackney carriages &c. each at .3 tons	19	5.7 tons		
	Bullock Carts (loaded) each at 1.1 tons	367	403.7 tons		
	Bullock Carts (unloaded) each at .25 tons	203	50.8 tons		
	Other Types of Vehicles e.g., Rickshaws, Cycles &c. each at .1 ton	553	55.3 tons	607.7 tons	33.8 tons.
	Pedestrians each at .05 tons	1018	50.9 tons		
	Cattle each at .06 tons	688	41.3 tons		
TOTAL WEIGHT OF TRAFFIC PER DAY OF 24 HOURS OVER WHOLE WIDTH OF ROAD		3019.0 TONS			
DITTO—PER FOOT WIDTH OF METALLED TRACK		167.8 TONS			

TRAFFIC CENSUS IN DISTRICT 24 PARGANAS

FOR ONE DAY OF 24 HOURS

(DIAMOND HARBOUR ROAD)

PLACE & TIME OF OBSERVATION ..		DIAMOND HARBOUR ROAD 8TH. MILE-FEB. 1938			
NATURE OF ROAD AT THE ABOVE PLACE		BITUMINOUS			
FULL WIDTH OF ROAD		32'-0"			
METALLED WIDTH OF ROAD		20'-0"			
TYPE OF TRAFFIC	KIND OF TRAFFIC	NUMBER OF EACH KIND	WEIGHT OF EACH KIND	WEIGHT OF EACH TYPE	WT. PER FOOT WIDTH OF METALLED TRACK
AUTO-MOBILE	Lorry (loaded) each at 3'5 tons	79	276'5 tons		
	Lorry (unloaded) each at 1'0 ton	54	54'0 tons		
	Bus each at 2'5 tons	118	295'0 tons	669'2 tons	33'5 tons
	Car each at '75 tons	58	43'5 tons		
	Motor Cycle each at '20 tons	1	'2 tons		
NON-AUTO-MOBILE	4 Wheeled Carts, hackney carriages &c. each at '3 tons	3	'9 tons		
	Bullock Carts (loaded) each at 1'1 tons	144	158'4 tons		
	Bullock Carts (unloaded) each at '25 tons	96	24'0 tons	371'8 tons	18'6 tons
	Other Types of Vehicles e.g., Rickshaws, Cycles &c. each at '1 ton	795	79'5 tons		
	Pedestrians each at '05 tons	2118	105'9 tons		
	Cattle each at '06 tons	52	3'1 tons		
TOTAL WEIGHT OF TRAFFIC PER DAY OF 24 HOURS OVER WHOLE WIDTH OF ROAD		1041'0 TONS			
DITTO—PER FOOT WIDTH OF METALLED TRACK		52'1 TONS			

APPENDIX VI.

A NOTE ON EXPERIMENTS WITH CUT-BACKS OF BITUMEN.

BY

MR. P. C. NEOGI, I.S.E.

INTRODUCTORY.

The Government of India, in the Department of Industries and labour, in their letter No. C 48 dated the 27th May 1936, sanctioned a grant from the reserve in the Road Fund account for conducting experiments on Ultra Low Cost Road Surfaces near about Calcutta. An estimate amounting to Rs. 20,000/- was sanctioned with concurrence of the Consulting Engineer to the Government of India (Roads), which covered a range of experiments with cut-backs of bitumen and probable maintenance cost for a period of 2 years. It was anticipated that the experimental stretches of road would be inspected by the members and delegates of the Indian Road Congress which, at that time, was thought would be held in Calcutta at the beginning of 1938.

GENERAL CLASSIFICATION OF EXPERIMENTS.

The experiments were divided into the following main categories :—

1. Stabilisation of freshly consolidated water-bound macadam with trap stone metal, by allowing a cut-back of bitumen to penetrate into the macadam to different depths of penetration by adjusting

- (a) the quantity of matrix,
- (b) the nature of surface, *viz.* dry or wet,
- (c) the interval allowed between the application of matrix and the blinding material, and
- (d) application of matrix in cold or hot state.

2. Surface painting with cut-back of bitumen on existing water-bound macadam which had become rough but where the water-bound macadam was sufficient to receive surface treatment.

3. Surface painting with cut-back of bitumen on freshly consolidated water-bound macadam in good shape.

4. Behaviour of different grades of cut-backs of bitumen on existing bitumen-painted surfaces, with a view to explore the possibility of—

- (a) Reviving bitumen which had hardened and cracked but under which the sub-base remained smooth.
- (b) Correcting a badly corrugated road (corrugations being due to the excess of bitumen at the surface);

- (c) Correcting a badly corrugated road (corrugations being due to a weak sub-base);
- (d) Maintenance of a bitumen-painted surface, which is fast developing pot-holes, due to any one of the causes referred to above.

It will be seen from the above details that the scope of the experiments covered a wide range, each having a particular importance of its own. Consideration now in greater detail of the experiments will possibly help in arriving at conclusions. These details are—

Item No. 1. Stabilisation of water-bound macadam freshly consolidated.

This is more or less of the nature of a semi-grout. The scope of the experiment was to have water-bound consolidation with varying depths of penetration of a cut-back of bitumen.

(a) Light traffic, met with beyond a radius of approximately 25 miles of Calcutta, the intensity of traffic not exceeding 500 tons per day of 24 hours, on a 12 feet wide road, traffic consisting mostly of iron-rimmed bullock-carts.

(b) Moderately heavy traffic, met with in and about Calcutta, the intensity of traffic being over 100 tons per day of 24 hours, on roads 12 feet in width.

It was assumed that by regulating the penetration of cut-back with the methods described earlier, different depths of penetration would be obtained, thus presenting suitable sub-bases for surface painting (as wearing course) under varying intensity of traffic. Surface painting may, however, be applied at a subsequent date according to requirement. The material to be used in surface painting may either be bitumen of 80-100 penetration applied hot or a cut-back of bitumen.

The underlying principle of conducting this experiment was to determine—

(i) to what extent the adoption of specification with higher percentage of bitumen than in surface painting (such as grout, premix carpet etc.) might be dispensed with, in the case of roads subjected to moderately heavy traffic,

(ii) to what extent the maintenance cost of miles of roads, normally heavily patch repaired with stone metal every year, could be reduced, by retaining the surface of the road in true shape and form, till the next programme of re-sectioning.

Item No. 2. Surface painting with cut-back of bitumen rough water-bound macadam.

There are many miles of roads the surfaces of which have become very rough but where the water-bound consolidation remains firm.

The scope of the experiment was to investigate the providing of treatment to such a surface, without having to resection it, (with the

possible chances of weakening the water-bound), but, at the same time, to ensure the correct quantity of surfacing material.

Attempts to paint rough surfaces with residual bitumen lead to excess at places which, under traffic, lead to corrugations on the surface but also increase the cost of surface treatments. Treatment of such surfaces normally should consist of a primer coat on the brushed surface and then a carpet of premixed chippings rolled to shape with a possible liquid seal on top with sand.

The cut-backs, however, offer a march over this method, in allowing a combined primer coat and mix-in-place carpet with the help of a drag-broom. By using different sizes of chippings, it is possible to smoothen a rough road by applying one or more courses of treatment as considered necessary, the number of courses depending mainly on the depth of depressions.

Item No. 3. Surface painting with cut-back of bitumen on freshly consolidated water-bound macadam.

The scope of the experiment was to ascertain if better results could be achieved, than the present day methods of surface paintings with hot bitumen, road tars or emulsions. The superiority claimed for cut-backs is that with their greater penetrative qualities, better adhesion with the water-bound macadam is obtained.

Item No. 4. Behaviour of different grades of cut-backs on existing bitumen painted surfaces which owing to some reason or the other, require replacement.

The scope of experiment under this sub-head was mainly to determine,

(i) to what extent bitumen, which has become apparently dead or hard, can be revived with the addition of cut-backs and to explore the field of use of such stuff instead of throwing it away,

(ii) to what extent softening of bitumen in a painted surface will take place and, with this information, to see to what extent this can be used in smoothening a corrugated bitumen painted surface with the addition of chippings, thereby ensuring a greater thickness of carpet with the correct quantity of matrix.

It may not be out of place to mention the following facts in connection with painted surfaces with bitumen.

Repainting of surfaces, particularly with hot bitumen, on a painted (bitumen) surface, which has shown signs of drying and becoming brittle, leads to failure as the new surface has no adhesion with the sub-base. It is, therefore, necessary to remove the date material which is not an easy operation to perform.

The range of penetration of residual bitumen used in all surface dressing must vary between 80 to 100 and this penetration (softness) should be maintained in the bitumen after all field operations are performed.

Bitumen with a lower penetration than 80, tends to become very hard and dry in the course of a few months, and begins to disintegrate with the impact of traffic, while bitumen possessing a higher penetration than 100 tends to become fluid making it impossible to retain the shape of the road unless the bitumen is unnaturally hardened with the addition of foreign materials such as road dust etc.. Attempts so far made in all surface treatments are to use a grade of bitumen which, after all field operations and with age, shall retain a penetration of 80-100; success in this has seldom been obtained. The reason for this is that bitumen hardens considerably under the various field operations and the factors which contribute to such hardening are:—

(a) Temperature,—the greater the temperature the greater the hardening.

(b) Thickness of film exposed,—the less the thickness the greater the hardening.

(c) Time of exposure of film under field operations,—the greater the time the greater the hardening.

It is claimed that cut-backs, if left sufficiently long in contact with bitumen, will get dissolved in the latter and form one mass, thereby softening the resulting mixture, but to what extent the resulting mixture will harden, is a matter which can only be found out by conducting a series of experiments. In all surface treatments, certain amount of hardening of bitumen at the surface is inevitable, but so long as the matrix in the remaining mass is unaffected and a perfect adhesion is established with the water-bound surface, there is no cause for apprehension.

DETAILS OF EXPERIMENTS.

Item No. 1.—Stabilisation of water-bound macadam and surface treatment on top.

The experiments under this section have been divided under 2 parts.

Part 1. Roads subjected to light traffic up to 500 tons per day of 24 hours on a 12-feet width.

Matrix used Liquid Asphalt No. 2.

Cut-back—40 percent bitumen (residual) 60 percent.

Road surface. It was decided to conduct the experiments on freshly consolidated water-bound macadam of trap stone metal but this could not be rigidly adhered to owing to circumstances explained later on.

Location 23rd mile of Calcutta-Jessore Road—Full mile.

35th mile of Calcutta-Jessore Road—First 6 furlongs and 360 feet.

It was originally intended to conduct experiments in the 23rd and in the 29th miles but this was subsequently changed.

Preparation of water-bound macadam and condition before experiment.

Water-bound consolidation of the 23rd mile of the Calcutta-Jessore Road was taken up during the driest months of the year i.e., April and May 1936. The reason for such abnormal treatment was to complete the experiments prior to the onset of the rainy season so that the experimental stretches might experience at least 6 months of traffic before inspection by the members and delegates of the Indian Road Congress. The date of the Road Congress being in the meanwhile deferred until the beginning of 1938, the consolidation was left over till December 1936 but in the meanwhile the surface had become considerably disturbed by cattle traffic.

Water-bound consolidation of the 35th mile of the Calcutta-Jessore Road was done during October and November 1936 and the surface was in very good shape. The 23rd mile is free from drippings of road-side trees, while 35th mile is subjected to heavy drippings.

Time of experiment.

23rd mile	..	..	..	..	December 1936.
35th mile	..	..	..	..	January 1936.

Variables.

The experiment was divided into 48 variables as stated below with 200-feet length of road-way under each variable and the details may be seen from the statement No. I attached herewith.

(a) Rate of application of matrix.

- (i) $1\frac{1}{2}$ gallons per 100 square feet of road surface.
- (ii) 2 gallons per 100 square feet of road surface.
- (iii) 3 gallons per 100 square feet of road surface.

(b) Time to apply blinding materials after application of matrix.

- (i) 2 to 6 hours in cases of (a) (i), (a) (ii), and (a) (iii)
- (ii) 18 to 24 hours in cases of (a) (i), (a) (ii), and (a) (iii)
- (iii) 36 to 48 hours in cases of (a) (i), (a) (ii) and (a) (iii)

(c) Nature of blinding materials :—

- (i) Sand.
- (ii) Cinder.
- (iii) Road-side dust.

(d) Nature of surface.

- (i) Dry.
- (ii) Damp.

Initial cost of surface treatment.

Rate of application of cut-back per 100 square feet.	Blinding materials and quantity per 100 square feet of surface.	Rate per 100 square feet of surface.	Rs.	As.	P.
1½ Gallons	Sand and Cinder at 2 cubic feet		1	10	9
1½ Gallons	Road dust at 1.5 cubic feet		1	5	9
2 Gallons	Sand and Cinder at 3 cubic feet		2	3	9
2 Gallons	Road dust at 2.5 cubic feet		1	12	6
3 Gallons	Sand and Cinder at 3.5 cubic feet		3	0	3
3 Gallons	Road dust at 3.0 cubic feet		2	8	0

N.B. Cost of cut-back liquid asphalt No. 2 at -/11/6 gallon including carriage

Cost of sand and cinder 15/- 100 cubic feet.

Cost of labour including lighting and guarding . 5/6 per 100 square feet.

Condition of surface after treatment.

Portion covered with 3 gallons of cut-back per 100 square feet remained in a very good condition, but the portions covered with 1½ to 2 gallons per 100 square feet failed in places.

In November 1937 it was decided that no useful purpose would be served in keeping such a great length of road under observation, so the 23rd mile was accordingly provided with a 2-inch grout as provided for in the project for improvement to the Calcutta-Jessore Road. It was further decided to preserve the experiments in the 35th mile for another year after attending to necessary repairs.

Maintenance Cost, 23rd mile.

Repairs were necessary to portions covered with 1½ and 2 gallons per 100 square feet. During one year and one month the experiment was kept under observation the following charges had to be incurred:—

2 tons liquid asphalt No. 2 at 160/- ton	Rs. 320/-
Labour charges	Rs. 30/-
	<hr/> Rs. 350/-

The area maintained.

3480 feet X 12 feet = 41,760 square feet.

Therefore, maintenance cost per 100 square feet Rs. 1/3/- per year.

Maintenance Cost, 35th mile.

Practically no repairs were done during the first year but several loose patches formed under heavy drippings from trees. The loose patches were first primed with cut-back liquid asphalt No 2, packed loose stone metal

and chips and the entire area under experiment covered with another seal coat at $1\frac{1}{2}$ gallons per 100 square feet covered with sand. Repairs were completed in April 1938 at a cost of Rs. 1/8/- per 100 square feet.

Conclusions.

Very little difference was observed with application on dry and wet surfaces. Rates of application of $1\frac{1}{2}$ and 2 gallons per 100 square feet were found to be inadequate. The application of blinding materials should be kept back as far as possible to allow sufficient penetration into the water-bound macadam. Even 3 gallons per 100 square feet is inadequate on a freshly consolidated water-bound macadam. 4 gallons per 100 square feet would be best if left over for 48 hours before application of blinding materials. The rate of penetration can be definitely checked with the early application of blinding materials. Of the three blinding materials sand, cinder and road-side dust, sand turned out to be the best. Treatment should be done immediately after consolidation and before the metal pieces start to get loose. This treatment is of distinct advantage on roads subjected to light traffic as the shape of the road can be retained in a very good shape at a small cost.

Part 2.—Roads subjected to moderately heavy traffic—1000 tons per day of 24 hours—12 feet wide road. Priming with cut-back followed by surface treatment with cut-back or hot bitumen and stone chips.

Matrix used. Liquid Asphalt No. 2. (10 percent cut-back) Socofix (20 percent cut-back).

Road surface. Freshly consolidated water-bound macadam surface was slightly loose and rough immediately before experiment.

Location. (a) 6th mile, Calcutta-Jessore Road—1st furlong.

(b) Strand Road—starting from Peel's statue

Details of experiment. 1st furlong of the 6th mile Calcutta-Jessore Road—Combination of (liquid asphalt No. 2 and Socofix: This length was resectioned with 4-inch consolidated new trap stone metal of the road during the month of May 1936, and in the month of September the same year was experimented upon. The area was divided into 2 parts—Parts A and B.

Note.—Parts A and B were further sub-divided into 2 parts each for surface treatment with liquid asphalt No. 2 on dry and damp surfaces.

In part A, surface treatment was made with 3 gallons of liquid asphalt No. 2 (applied cold) after cleaning the surface and this was allowed to stand for 24 hours and then covered with stone chips and sand. Traffic was allowed for a period of 3 months. The surface was then given a mix-in-place carpet

with Socofix at 4 gallons per 100 square feet and trap stone chips $\frac{3}{4}$ inch to 1 inch at 5 square feet per 100 square feet. The mix-in-place was effected by means of a drag-broom. The entire surface was then given a liquid seal of Socofix at 1 gallon per 100 square feet and covered with sand.

In part B, the road surface was primed with liquid asphalt No. 2 at 4 gallons per 100 square feet applied hot-treatment made both on dry and damp surfaces. Stone metal and chips and sand were then applied to fill up depressions and the road was opened to traffic after 24 hours.

The surface after 3 months was given a course of mix-in-place with drag-brooming using Socofix at 4 gallons per 100 square feet and stone chips $\frac{3}{4}$ inch to 1 inch at 5 cubic feet per 100 square feet and covered with sand after rolling.

The experiment showed signs of failure after 4 months of laying. Repairs to the pot-holes were done with Socofix and stone chips, cost of maintenance from date of experiment to 1st January 1938 being Rs. 4/8/-. 100 square feet.

Conclusion.

The experiment was considered to be a failure. The stretch of road selected had to carry very heavy traffic. This experiment may be of use on a road carrying light traffic.

ITEM No. 1, (Part 2).
INITIAL COST OF EXPERIMENT.

Name of experiment.	Area under experiment	Liquid Asphalt No. 2	Labour for priming with AL2	Socofix	Labour for mix-in-place.	Stone chips ¾" to 1"	Sand.	Cost per 100 Sft.
Priming with liquid asphalt No. 2 @ 3 gallons per 100 square feet & mix-in-place with cut-back Socofix @ 4 gallons per 100 square feet with stone chips and sand.	5940 Sft.	178.2 Gall. @-/11/- = 123/8/0	5940 Sft. @-/5/--% = 18/8/0.	5940 Sft. @ 4 Gall. % 23.8 Gall. @ -/11/-Gall. = 164/-	5940 Sft. @-/6/--% = 22/4/-	318 Cft. @-/37/--% = 118/-	300 Cft. @-/15/- % 45/-	Rs. As. P. 8 4 0 (Approx.)
Priming with liquid asphalt No. 2. @ 4 gallons per 100 square feet and mix-in-place with cut-back Socofix @ 4 gallons per 100 square feet with stone chips and sand.	5940 Sft.	237.6 Gall. @-/11/- = 163/6/0	Same as above 18/8/-	Same as above 164/-	Same as above 22/4/-	Same as above 118/-	Same as above 45/-	9-4-0

Note.—The above figures do not take into account cost of new water-bound consolidation. The total cost of water-bound consolidation is Rs. 1650/-.

Item No. 2.—Surface painting with cut-back of bitumen on existing water-bound macadam which has become rough, but is strong enough to receive surface treatment.

Location. 2nd half of 28th mile Calcutta-Jessore Road.

Condition before treatment. The water-bound consolidation was done during the months of April and May 1936 under conditions identical with those in the 23rd mile. The experiment was, however, conducted during the latter part of December 1936 and the beginning of January 1937. The surface was extremely rough and the water-bound macadam was loose due to cattle traffic. The surface of the road was watered and rolled to consolidate the stone metal slightly. So the condition of surface before the experiment was rough but the water-bound was firm. Depressions in places were about $1\frac{1}{2}$ inches

Matrix used. Socofix—cut-back, 20 per cent.

Area covered by experiment. = 2580 feet \times 12'-0" = 30,960 square feet.

Details of experiment. The road surface was brushed clean and then moistened with water slightly. Cut-back (Socofix) was then applied to the surface at the rate of 6 gallons per hundred square feet and allowed to penetrate for a period of 2 hours. The stone chips of sizes varying from 1 inch to $\frac{3}{4}$ inch at the rate of 7 cubic feet per hundred square feet approximately, was then spread on the road surface. The drag-broom was first tied to a lorry and dragged along the road but this method was found to be unworkable as the engine got unduly hot and the operation had to be postponed. Drag-brooming was then done with manual labour; about 12 coolies were found to be sufficient; 10 to 12 turns of drag-brooming with application of matrix at dry patches by means of perforated cans, was found to be sufficient to mix the aggregate with matrix thoroughly. The surface was then covered with a thin layer of sand and rolled thoroughly with a 10-ton steam road roller. After rolling, the surface was covered with a layer of sand and opened to traffic after 10 to 12 hours.

ITEM No. 2

INITIAL COST OF EXPERIMENT.

Type of experiment.	Area experi- mented upon.	Socofox.	1" stone chips.	$\frac{3}{4}$ " stone chips.	Sand	Watering	Labour	Total.	Rate per % S. ft.
Priming with Soccofox @ 6 gallons per hundred square feet. Mix-in-place with Drag-broom using 1" to $\frac{3}{4}$ " chips @ 7 cubic feet per hund- red square feet.	2580 x 12 = 30960 S. ft.	1858 Gal. @ 11/- Rs. 1277/-	1900 C. ft. @ 34/- Rs. 646/-	350 C. ft. @ 38/- Rs. 133/-	350 C. ft. @ 15/- Rs. 53/-	L. S. Rs. 30/-	30960 S. ft. @ 1/8- Rs. 464/-	Rs. 2603/-	Rs. 8/6/-

Note :—Cost of consolidation of trap stone metal during dry months (amounting to Rs. 255/-) not taken into account.

Condition after experiment—It was noticed during the beginning of the year 1938 that pot-holes are appearing at the centre of the road due to the undue hardening of the cut-back.

Maintenance Cost—Upto the beginning of the year 1938 maintenance cost is nil. A few pot-holes have been repaired since April 1938 and the cost is approximately Rs. -/11/- per 100 square feet.

Conclusion—Provided a softer base of bitumen is adopted in making cut-back, this will provide an excellent treatment of rough water-bound macadam.

Item No. 3.—Surface painting with cut-back of bitumen on freshly consolidated water-bound macadam in good shape.

Location. 1st half of 28th mile, Calcutta-Jessore Road.

Matrix used. Socofix.

Variables. Painting with 3 gallons per hundred square feet, and
Painting with 4 gallons per hundred square feet,
with Trap stone chips $\frac{3}{4}$ inch to $\frac{1}{2}$ inch size.

Details of experiment. The existing surface was brushed clean, matrix was applied at the rate of 4 gallons per hundred square feet and was allowed to stand for 6 hours and then covered with trap stone chips $\frac{3}{4}$ inch to $\frac{1}{2}$ inch in size and rolled with a 10-ton steam road roller. The surface was then covered with a layer of sand and opened to traffic.

Initial cost of experiment. Average cost of experiment worked out as follows :—

Area under experiment = 32,400 square feet.

Socofix—1296 gallons	at -/11/- a gallon	Rs. 891/-
$\frac{1}{2}$ " Stone chips 697 C. ft.	at 40/- % C. ft.	Rs. 279/-
$\frac{3}{4}$ " Stone chips 853 C. ft.	at 38/- % C. ft.	Rs. 324/-
Sand 356 C. ft.	at 15/- % C. ft.	Rs. 52/-
Labour Charges—32,400 S. ft.	at -/8/- % S. ft.	Rs. 162/-

Rs. 1708/-

Deduct cost of surplus chips about

300 C. ft. at 40/- % C. ft.

Rs. 120/-

Rs. 1588/-

Therefore, cost per hundred square feet is Rs. 5/- (say).

The condition of the road was very good upto the beginning of January 1938 but since then there have been signs of hardening of the matrix leading to formation of a few pot-holes. These have been repaired with stone chips and Socofix, maintenance cost being 0-11-0 per hundred square feet.

A softer grade of bitumen should be used in making the cut-back to prevent undesirable hardening.

Item No. 4.—(a) Reviving bitumen which has hardened and cracked but the sub-base remaining smooth.

This experiment has been conducted over several miles of the Budge Budge road, the surface painting of which suddenly started failing during December 1937.

The treatment was mainly in applying Liquid Asphalt No: 2 at the rate of 1 to $1\frac{1}{2}$ gallons per hundred square feet and allowing it to mix with the

hardened bitumen for 48 hours and then covering it with sand. In the course of one month, the cut-back got mixed with the hardened bitumen and softened the whole mass. Formation of further pot-holes was effectively stopped, and a smooth surface was obtained which was subsequently painted with hot bitumen and chips. The rate of application of sand was 2 cubic feet per hundred square feet area. The cost per mile worked out to Rs. 600/- per mile and was amply paid back by the resultant saving of hot bitumen applied later on in wearing course. This treatment corrected the corrugations in the surface to a considerable extent.

Item No. 4.—(b) Correcting a badly corrugated road, corrugations being due to the excess of bitumen at the surface.

In the absence of stretches of such surfaces, this experiment could not be conducted. An idea of the proposed experiment may be obtained from the details of (a) and (c) under item 4 of the experiment.

Item No. 4.—(c) Correction of a badly corrugated road, corrugations being due to weak sub-base.

Location. 1st half of 13th mile, Calcutta-Jessore Road.

Condition before experiment. The surface painting was in fair condition but was very uneven but not corrugated.

Details of experiment. The layer of surface painting was carefully picked up and broken up into small pieces. The water-bound macadam was found to be about 2 inches thick and was resectioned and consolidated, with old and new stone metal to a thickness of 4 inches, in September 1936. Blinding with screenings from the road was applied on top of the sub-base of Jhama metal in a thin layer before putting down the stone metal. This was then consolidated with a 10-ton steam road roller, profuse watering being applied during rolling. The broken pieces of bitumen scum taken out from the painted surface were used as blinding material on top of the stone metal during rolling and thoroughly consolidated. After a month the surface was treated with a liquid seal of cut-back liquid asphalt No. 2, at 4 gallons per hundred square feet and allowed to penetrate for 24 hours and then topped with sand.

Initial cost of experiment. Rs. 4-4-0 per hundred square feet excluding the cost of water-bound macadam.

Maintenance. Cost of maintenance from date of experiment for about one year was Rs. 1/3/- per hundred square feet.

Condition after experiment. After one year of experiment, the surface showed signs of hardening and a number of pot-holes formed.

The road surface was then given a coat of surface painting with hot bitumen (Socony E grade 105) and stone chips $\frac{3}{4}$ inch to 1 inch size. Bitumen was used at 22 gallons per hundred square feet and chips at 5.5 cubic feet per hundred square feet.

Conclusion. The cut-back combined well with the seum of bitumen but the resultant mass hardened and had to be covered with hot bitumen of 80-100 penetration and stone chipped. The unevenness in the road surface did not appear again.

Item No. 4.—(d) Maintenance of a bitumen painted surface which is fast developing into pot-holes due to any one of the causes referred to above.

Location. 2nd half of 13th mile, Calcutta-Jessore Road.

Details of experiment. It was treated with Socofix at 4 gallons per hundred square feet and stone chips 1 inch size at 5 cubic feet per hundred square feet and finished with mix-in-place operation and rolled with Steam Road Roller in December 1936.

Initial cost of experiment. Rs. 0-8-3 per square yard.

APPENDIX VII.

List of Papers in Annual Proceedings.

Volume I—1934.

1. Objects and Organisation of a Permanent Indian Roads Congress, by K. G. Mitchell, C.I.E., I.S.E.
2. (a) Recent Methods used for the Treatment of Roads with Bitumen and Tar in Delhi Province, by A.W.H. Dean, M.C., I.S.E.
 (b) The Trend of Development in the United Provinces in the matter of improving Road Surfaces with special reference to recent Experiments, by C. F. Hunter, M. Inst. C.E., A.M.I.E., (India).
3. Earth Road Construction and Maintenance by Machinery, by G. W. D. Breadon.
4. Earth Road Development and Stabilisation with Gravel, by Lieutenant-Colonel A. V. T. Wakley, D.S.O., M.C., R.E.
5. (a) Progress made in the use of Tar and Bitumen in the Punjab since the last International Roads Congress, in Washington in October 1930, by S. G., Stubbs, O.B.E., I.S.E.
 (b) Notes on the Uses of Tar, Bitumens and Emulsions in the Punjab, by R. Trevor-Jones, M.C., A.M. Inst. C.E.
6. Asphalt Roads by G. G. C. Adami, B.A. (Cantab).
7. The Use of Cement Concrete for the Construction of Roads in the Bombay Presidency, by L. F. Greening.
8. Cement Concrete Roads, by W. J. Turnbull, B.Sc., M. Inst. C.E.
9. Concrete Roads in Hyderabad (Deccan), by M. A. Zeman.
10. Corrugation of water-bound macadam road surfaces in the Bombay Presidency, and a Cure, by Henry J. M. Cousens.
11. Notes on the Plant Used for Quarrying and Granulating and Operating Costs of the Gauhati-Shillong Road, Khasi and Jaintia Hills Division, Assam, by B. F. Taylor, V.D.
12. Some Physical Aspects of Tyres and Roads, by G. L. W. Moss.
13. Test-Tracks—A Suggestion, by C. D. N. Meares.

Volume II—1936.

14. Analysis of Delhi Road Traffic Census, by R. L. Sondhi, I.S.E.
15. A study of the Relationship between Vehicular Traffic and Road Surfaces as affecting the selection of an Economic Road Surface, by H. P. Sinha, I.S.E., and A. M. Abbasi.
16. Traffic Census and Road Diagrams, by Lieutenant-Colonel W. de H. Haig, D.S.O.
17. Economics of Road Maintenance, by S. Bashiram, I.S.E.
18. Necessity for Surface Treatment of Important Tourist lines and some aspects of Economical Work in that direction, by V. S. Srinivasaragha Achariar Ayl.
19. Treatment with Molasses of the Bangalore-Mysore Road, by Diwan Bahadur N. N. Ayyangar, B.A., L.C.E., M.I.E. (India), I.S.E.
20. The Road Problem in India with some Suggestions, by Colonel G. E. Sopwith.
21. General Review of the Results of Recent Road Experiments in India as revealed by Modern Practice, by K. G. Mitchell, C.I.E., I.S.E.
22. Road Research and Results, by C. D. N. Meares.
23. (a) Roads in Rural Areas (Village Roads), by Honorary Captain Rao Bahadur Choudhry Lal Chand, O.B.E., M.L.A.
 (b) Gravel Roads, by Diwan Bahadur N. N. Ayyangar, B.A., L.C.E. M.I.E. (India), I.S.E.
 (c) Vitrified Bricks for Surfacing Roads in Deltaic Districts, by G. Gopala Acharya.
24. Oil as a Binder for Earth and Gravel Roads, by T. G. F. Hemsworth, B.A., B.A.I., I.S.E.
25. Cement-bound Roads, by W. J. Turnbull, B.Sc., M. Inst. C. E.
26. The Necessity for a Reasonably Uniform Standard Loading for Design of Concrete Bridges and a Suitable Loading for Such and Other Types of Bridges on Highways in India, by M. G. Banerji, B.A., B.E., A.M. Inst. M. and Cy. E., M.A.E., F.Sc.
27. Design of highway bridges. The necessity for an All-India Specification, by W. A. Radice, B.A., A.M.I.C.E., G. Wilson, B.Sc., A.M.I.C.E. and P. F. S. Warren, B.A., A.M.I.C.E.
28. Permissible Stresses in Concrete Bridge Design, by W. J. Turnbull, B. Sc., M. Inst. C. E.
29. Regulation and Control of Motor Transport in Mysore, by H. Rangachar, M. A.
30. The Construction of the Shillong-Jaintiapur Road in the Khasi Hills, Assam, by F. E. Cormack, I.S.E.
31. A Method of Rapid Road Reconnaissance, by Captain (now Major) W. G. Lang-Anderson, R. E.

Volume III 1937.

32. Some Notes on the layout of Rural and Suburban Roads in the Punjab, by R. Trevor-Jones, M.C., A.M. Inst. C.E.
33. Roads and Public Health in India with special reference to malaria, borrow pits, and road dust, by Raja Ram, B.Sc., A.M. Inst. C.E., F.R. San. I., M.I.E. (India).
34. Further Notes on treatment of Roads with Bitumen and Tar in Delhi Province, by A. W. H. Dean, M.C., I.S.E.
35. Economy and Developments of Bonded Brick Concrete Roads, Plain and Reinforced, by A. K. Datta, B.E., M.I.E. (India), M.A.E.
36. Ways and Means of Improving the Bullock-Cart, by G. L. W. Moss.
37. Indian "Road-Aggregates", Their Uses and Testing, by R. L. Sondhi, I.S.E.
38. Submersible Bridge across Parbati River at Mile 231, Agra-Bombay Road, by Rai Bahadur S. N. Bhaduri, B.A., C.E., M.I.E. (India).
39. Optimum Weight of Vehicles on extra municipal Roads, by K. G. Mitchell, C.I.E., I.S.E.

Volume IV—1938.

- A. (i) A Method of Calculating the Stability of Braced Pile Piers, by Guthlac Wilson, B.Sc., A.M.I.C.E., A.M. Am. Soc. C.E.
- (ii) The Dhakuria Lake Bridge, by Guthlac Wilson, B.Sc., A.M.I.C.E., A.M.I.C.E., M.I.E. (India).
- B. Franki Pile Foundation for Road Bridges, by W. A. Radice, B.A., A.M.I.C.E.,
- C. Reinforced Cement Concrete Bridges of 24 feet span constructed in Gwalior State, by Rai Bahadur S. N. Bhaduri, B.A., C.E., M.I.E. (India).
- D. Reinforced Concrete Bridge across the Godavari River at Shahgad in Hyderabad State, by Dildar Hosain, B.E., M.I.E. (India).
- E. Safe Wheel Loads for Indian Roads, by K. G. Mitchell, C.I.E., I.S.E., and Jagdish Prasad, C. E.
- F. Roads under Local Bodies and how to Maintain them, by Rai Sahib Fateh Chand.
- G. Corrugations on Road Surfaces, by G. B. E. Truscott.
- H. An Aspect of Traffic Statistics, by Ian. A. T. Shannon.

Volume V—1939.

- I. Some Notes on Submersible Bridges, by D. Nilsson, B.Sc., M.I. Struct E.
 - J. Design of Reinforced Concrete Bridges of Short Spans for Indian Roads, by Brij Mohan Lal, I.S.E.
 - K. (i) Collection of Material for and Consolidation of Water-bound Macadam, by R. Trevor-Jones, M.C., M.Inst. C.E., I.S.E.
 (ii) Layout of Roads, by R. Trevor Jones, M.C., M. Inst. C.E., I.S.E.
 - L. Some Aspects of Bituminous Road Construction in India, by Colonel G. E. Sopwith, M.C., and W. A. Griffiths.
 - M. Ribbon Development, by A. S. Trollip.
 - N. Soils in Relation to Roads, A Bibliological Study, by G. W. D. Breardon.
 - O. The Use of Soil Stabilization in Un-metalled and Metalled Roads in India, by Sita Ram Mehra, Assoc. M. Inst. C.E.
 - P. Revitalization of Tarred or Bitumened Surfaces by Mix-in-Place Methods using Cut-Back Asphalt, by Captain R. C. Graham, R. E.
 - Q. Surface Treatment of Concrete Roads when Outworn, by W. A. Radice, V.D., B.A. (Cantab), A.M., Inst. C.E., M. Inst. I.E.
 - R. A Serious Failure in the Painting of a Steel Highway Bridge, by W. L. Murrell, B.C.E., (Melb.), A.M. Inst. C. E.
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APPENDIX VIII

List of Members
(Corrected upto 1.10.1939)

ORDINARY MEMBERS.		
Date of election.	Name.	Address.
6.1.1938	Abdul Hai	Assistant Engineer, Asifabad, Hyderabad (Deccan).
3.3.1936	Acharya, G. Gopala	P. A. to Superintending Engineer, Papanasam Hydro Thermal Electric Scheme, Old High Court Buildings, Madras.
7.12.1936	Adalja, M. T.	Chief Engineer of Baroda State, Anand Bungalow, Jail Road, Baroda.
22.11.1937	Adke, A. S.	Engineer, District Local Board, Dharwar.
26.5.1937	Adshetti, G. K.	6, Kotak House, Maharashtra Road, Karachi.
3.3.1936	Ahmed, Khairuddin	Executive Engineer, P. W. D., Hyderabad (Deccan).
27.10.1936	Ahsan Yar Jung Bahadur, Nawab	Chief Engineer and Secretary to Government P.W.D., Hyderabad (Deccan).
5.12.1938	Ajwani, H. J.	Assistant Engineer, Khairpur Mirs', Sind.
11.7.1939	Akhtar, S. E.	Assistant Engineer, Ranchi.
10.7.1936	Ali Ahmed	Superintending Engineer, P. W. D., Shillong.
6.1.1938	Ali, Mirza Mehdi	District Water Works, Hanamkunda (Nizam's Dominions).
3.2.1939	Amir, S. A.	Executive Engineer, Hazaribagh Division, Hazaribagh, (Bihar).
6.1.1938	Anwarullah	Superintending Engineer, Osmania University Buildings Project, Hyderabad (Deccan).
3.3.1936	Arifuddin, Syed	Principal, Osmania Engineering College, Hyderabad (Deccan).

Date of Election.	Name.	Address.
5.1.1938	Assudullah, Mohammed	Divisional Engineer, H. E. H. Nizam's Dominions, Bhir.
3.3.1936	Ayyangar, Diwan Bahadur N. N.	Chief Engineer of Mysore, P. W. D Bangalore.
3.3.1936	Ayyangar, M. R. Duraiswamy	Municipal Engineer, Tanjore.
28.9.1936	Ayyangar, M. S. Duraiswami	Chief Engineer, Travancore State Trivandrum.
3.3.1936	Ayyar, Rao Sahib N. Balakrishnan	District Board Engineer, Tinnevely.
3.3.1936	Ayyar, A. Nageswara	Special Engineer for Road Development, Madras.
3.3.1936	Ayyar, K. Rangaswamy	State Engineer, Pudukotah, (Trichinopoly).
3.3.1935	Ayyar, K. Tirumalaiswami	District Board Engineer, Saidapet
24.2.1937	Bagchi, C. C.	Civil Engineer incharge of Buildings and Roads, Lucknow University, Lucknow.
6.1.1937	Bakshi, J.	Executive Engineer, Bhagalpur.
13.12.1938	Balakrishnayya, P.	District Board Engineer, Cuddapah.
1.1.1938	Bamji, H. F.	Chief Electrical and Mechanical Engineer, Dawn Hills, Ferguson Road, Bombay 17.
3.3.1936	Banerjee, M. G.	Controller of Stores, Calcutta Corporation, 149, Lower Circular Road, Calcutta.
10.9.1936	Banerji, S. K.	Assistant Engineer, Rewa, (Central India).
3.3.1936	Banerji, Rai Sahib Tulsidas	Assistant Garrison Engineer, Jubbulpore.
10.1.1939	Bapat, R. S.	State Engineer, Phaltan State, District Satara.
15.6.1939	Bansor, H. S.	Sub-Divisional Officer, Military Engineer Services, Ghangora, Dehra Dun, (United Provinces).
8.9.1937	Barua, H. P.	Executive Engineer, P.W.D., Silchar (Assam).
5.11.1936	Barua, K.	Assistant Engineer, P. W. D., Barpeta.

Date of election.	Name.	Address.
3.3.1936	Bashiram, S.	Superintending Engineer, Roads, and Secretary, Communications Board, Punjab, Lahore.
5.3.1938	Basu, H. L.	District Engineer, Balasore.
4.3.1939	Bazaz, Sham Lal	Assistant Quantity Surveyor, Central Public Works Department, New Delhi.
3.3.1936	Bedekar, K. M.	Executive Engineer, P. W. D., Karwar.
3.3.1936	Bedekar, V. P.	State Engineer, Miraj Senior (Deccan State).
31.3.1939	Behera, S. S.	State Engineer, Gangpur State, P. O. Sundargarh, Via Jharsuguda (B.N. Ry.).
23.3.1937	Bennet, C. M.	Executive Engineer, P. W. D., Koraput Division, Koraput (Orissa).
3.3.1936	Bhaduri, Rai Bahadur S. N.	Chief Engineer, P. W. D., Gwalior.
17.1.1938	Bhagat, D. G.	Assistant Engineer, C/o Special Road Engineer in Sind, Karachi.
22.6.1936	Bhalla, Prem Nath	District Engineer, Holkar State, P. W. D., Garoth.
3.3.1936	Bhandarkar, G. P., M. B. E.	Chief Engineer, Holkar State, Indore
23.12.1937	Bhargava, K. N.	Assistant Engineer, Roads, Alwar.
18.8.1936	Bharucha, M. D.	C/o the All-India Construction Company Limited, Wittet Road, Ballard Estate, Bombay.
3.4.1939	Bhate, K. G.	Assistant Engineer, P. W. D., Godhra.
3.3.1936	Bhatnagar, Jagmohan Lal	State Engineer, Jhalawar State, Brijnagar, (Rajputana).
3.3.1937	Bhatt, Upendra J.	State Engineer, Bhavnagar State.
28.3.1938	Bhattacharya, H.	Assistant Engineer, Department of Communications and Works, Khulna.
3.12.1937	Bhattacharya, N.	Executive Engineer, (B. & R.), Jaipur.
3.3.1936	Bhave, Rao Saheb V. G.	State Engineer, Sangli.

Date of election.	Name.	Address.
21.2.1938	Bhuyan, M. N.	Executive Engineer, Northern Division, Cuttack.
24.10.1936	Bishamber Dyal	District Engineer, Rohtak.
27.1.1937	Bisht, M. S.	Executive Engineer, P. W. D., Allahabad.
4.3.1939	Biswas, N. N.	State Engineer, Jashpur State, Eastern States Agency, <i>via</i> Ranchi.
20.12.1937	Blomfield, D. J.	Chief Engineer, Communications and Works Department, Calcutta.
23.9.1937	Bose, A. N.	Superintending Engineer, Presidency Circle, 8, Lyons Range, Calcutta.
12.4.1938	Bose, K. M.	District Engineer, Sambalpur.
3.3.1936	Breadon, G. W. D.	District Engineer, Gurdaspur (Punjab).
12.6.1936	Brown, G. A. M.	Superintending Engineer, Northern Circle, P. W. D., Peshawar.
6.4.1936	Browne, C. A.	Executive Engineer, Motihari Division, Motihari, Bihar.
3.3.1936	Budhiraja, Balwant Singh	State Engineer, Nabha.
3.3.1936	Bullen, E. G.	Officiating Executive Engineer, Southern Shan States, Taunggyi, Burma.
3.3.1939	Campbell-Gray, T.	Shalimar Tar Products Limited, P. O. Box 391, Madras.
20.1.1937	Chadda, Ulfat Rai	Military Engineer Services, Nowshera Cantt.
3.3.1936	Chakravarti, S. N., M. B. E.	Municipal Engineer, Delhi.
10.3.1939	Chakravarti, S. N.	Municipal Engineer, Dacca, P. O. Bagra.
7.3.1939	Chambers, J.	Superintending Engineer, Communications and Works, Oakdene, Darjeeling.
17.3.1938.	Champalal	Executive Engineer, Montgomery Provincial Division, Montgomery.

Date of election.	Name.	Address.
14.3.1936	Chance, P. V.	Chief Engineer, P. W. D., Central Provinces and Berar, Nagpur.
4.3.1939	Chatterjee, G. C.	State Engineer, Udaipur State, P. O. Dharamjaygarh (B. N. Ry.).
14.4.1936	Chatterjee, S. C.	Officiating Superintending Engineer, Central Circle, Calcutta.
3.3.1936	Chatterton, K.	Manager, Structural and Bridge Building Department, Burn & Co. Limited, Calcutta.
4.3.1937	Chaudhry, Abid Raza	Assistant Engineer, P. W. D., North Sylhet Buildings Sub-Division, Sylhet (Assam).
7.8.1936	Chaudhry, Bidhubhushan	Assistant Engineer, P.W.D., Assam, P. O. Silchar.
7.1.1938	Chenoy, Faridon S.	Executive Engineer, His Exalted Highness the Nizam's P. W. D., Jehangir Bagh No. 12 Chilkalguda, Secunderabad.
3.3.1936	Cherian, M. P.	Municipal Engineer, Tuticorin.
7.6.1938	Chinchankar, K. B.	The New India Construction Company, Karad (Satara).
14.8.1939	Choksi, B. K.	C/o P. W. D., Chalisgaon, East Khandesh.
9.6.1936	Chopra, A. N.	Superintending Engineer, P. W. D., 80, Budh Road. Rangoon Cantt. (Burma).
2.6.1938	Chopra, P. C. .	Assistant Engineer, P. W. D., Wardha, (Central Provinces).
20.1.1937	Chowdhry, S. P.	Assistant Engineer, Tezpur, District Derranga (Assam).
4.3.1939	Chowdhry, Ram Narain	Assistant Engineer, Jodhpur P. W. D., Yellow House, Pali Marwar.
20.5.1936	Clayton, Major R.	Engineer-in-Chief's Branch, Army Headquarters, Simla.
3.12.1938	Cochrane, G. A. D.	Executive Engineer, Akola, (Berar).
10.7.1936	Cocksedge, H. G.	P. W. D., Dhubri, (Assam).

Date of election.	Name.	Address.
3.3.1936	Colabawala, Khan Bahadur J. R.	State Engineer, Khairpur Mirs' (Sind).
10.7.1936	Cormack, F. E.	Superintending Engineer, Northern Circle, P. W. D., Shillong.
6.1.1938	Daftary, G. D.	Superintending Engineer, Northern Circle, Bombay P. W. D., Secretariat, Bombay.
5.2.1938	Dalal, C. C.	C/o The Imperial Bank of India Limited, Hyderabad (Deccan).
13.5.1936	Dam, S. C.	P. A. to the Chief Engineer, Bengal Communications and Works Department, Calcutta.
14.5.1938	Dangoria, Chandulal C.	Hughes Town, Murshidabad Road, Hyderabad (Deccan).
10.7.1936	Das, B. C.	Sub-Engineer, Local Board, Tezpur (Assam).
1.10.1938	Das, P. C.	Sub-Divisional Officer, P. W. D., Cuttack.
22.1.1937	Das Gupta, J. N.	Assistant Engineer, 29, Nicholson Road, Delhi.
6.2.1939	Das Gupta, J. N.	27, Lansdowne Terrace, Calcutta.
3.3.1936	Das Gupta, N.	Asphalt Engineer, Standard Vacuum Oil Company, Calcutta.
3.3.1936	Datta, A. K.	Consulting Engineer, and Master Builder, 5, Hastings Street, Calcutta.
10.7.1936	Datta, D. C.	Assistant Engineer, Kohima, Naga Hills, Assam.
10.7.1936	Datta, S. K.	Sub-Divisional Officer, South Shillong Sub-Division, Pynursla, Shillong.
3.3.1936	Dave, D. P.	District Engineer, Akola.
27.4.1937	De, B. C.	Assistant Engineer, P. W. D., P. O. Sylhet, Assam.
15.1.1937	Dean, A. W. H.	Superintending Engineer, Delhi Province, New Delhi.
7.8.1936	Desai, D. S.	C/o Messrs. Braithwaite & Company (India), Limited, Hide Road, Calcutta.

Date of election. .	Name.	Address.
3.3.1936	Devasthala, K. B.	District Engineer, District Council, Yeotmal, Central Provinces.
3.3.1936	Devi Dayal	Executive Engineer, P. W. D., Dibrugarh, (Assam).
20.6.1939	Dhamani, Pessumal Narumal	Assistant Engineer, Seepage Sub-Division and P. A. to the State Engineer, Khairpur Mirs', Sind.
25.1.1939	Dhanrajan, S. H.	Municipal Engineer, Coimbatore (Madras).
29.3.1937	Dhesi, Dilbagh Singh	State Engineer, Saugrur (Jind State)
6.1.1937	Dighe, V. A.	Chief Engineer, Janjira State, Janjira Murud.
18.12.1937	Dildar Hosain	Assistant Chief Engineer, H.E.H. the Nizam's P. W. D., Hyderabad (Deccan).
1.10.1939	Divatia, S. S.	Executive Engineer, P. W. D., Kaira.
26.5.1938	Doshi, A.G.	Chenkaladi, Ceylon.
16.2.1937	Doshi, M. M.	C/o The Indian Hume Pipe, Lucknow.
1.12.1937	Dunbar, H. M	C/o The Concrete Association of India, Forbes Buildings, Homre Street, Bombay.
3.12.1937	Durrani, N.	District Board Engineer, Bellay (Madras).
24.9.1936	Dutta, G. N.	Sub-Divisional Officer, P. W. D., Lahan, Shillong.
18.8.1936	Eccleston, W. T	Executive Engineer, 4, Civil Lines, Rawalpindi.
4.1.1939	Edgar, S. G.	Superintending Engineer and P. W. D., Minister, Government of Jodhpur, Jodhpur.
29.10.1936	Edibam, N. R.	D57/35, Aurangabad Road, Benares.
3.3.1936	Edwin, J. W.	Executive Engineer, C. and M. Station Municipality, Bangalore.
3.3.1936	Endlaw, D. N.	Sub-Divisional Officer, Central P. W. D., Queens Road, Bombay.

Date of Entry	Name	Address
3.3.1936	Farr, G.	Sd. District Officer, Bannu Civil Work Sd. Division, Bannu.
3.4.1937	Fatchi Chaud Rai Sahib	Secretary-Engineer, District Board, Piprot.
11.6.1937	Fletcher, C. J.	C. & H. Turner, Morrison and Co. Limited, Calcutta.
3.3.1939	Fitcherott, R. A.	Superintendent Engineer, Central Circle, Poona.
2.12.1938	Fleury, W. R.	Executive Engineer, Sahabpur, O.P.W.
3.3.1939	Gan Rai, Rai Bahadur K. J.	State Engineer, Jurgalla, (Kathia- wadi).
14.9.1939	Gandhin, V.	Engineer, Radha, Park Town, Madras.
30.9.1939	Gangadhara, K. S.	Assistant Engineer, No. 4 Sub- Division, Gadag (Mysore State).
3.3.1939	Ghanekar, Y. K.	Assistant Engineer, Nagar Im- provement Trust, Nagpur.
13.2.1937	Gharpure, A. V.	Superior Engineer, The Indian Homes Pipe Company, Limited, Jambulpur.
3.3.1936	Gaur, Rai Sahib Uttam Chand	Assistant Garrison Engineer, Military Engineer Service, Civil Lines, Quetta.
3.3.1936	Ghose, S. K.	Assistant Engineer, P. W. D., Chunab, (Bihar).
4.8.1936	Gilbert, L. B.	Chief Engineer, Public Works Department, Buildings and Roads Branch, Lucknow.
26.4.1937	Gilmore, E. F. G.	Director, Industrial Research Bureau Indian Stores Department, New Delhi.
8.3.1938	Gannaparakaram, N. T.	L. E. Assistant Engineer, Berwada.
3.3.1936	Goghari, D. W.	Retired State Engineer, Bhavnagar.
3.3.1936	Golwala, P. E.	Civil Engineer, C. & Chief Engineer, Bombay Port Trust, Ballard Estate, Fort Bombay.

Date of election.	Name.	Address.
15.2.1937	Gopal Das	Sub-Divisional Officer, P. W. D., Rohtak.
29.1.1938	Gopalan, M.	Special Superintending Engineer, Capital Works Circle, Kachiguda, Hyderabad (Deccan).
7.2.1938	Goswami; S. M.	Assistant Inspector of Local Works, P. O. Motihari, Champaran.
3.3.1936	Gough, D. E.	Representative of the Society of Motor Manufactures and Traders Limited, 41, Nicol Road, Ballard Estate, Bombay.
23.12.1937	Graham, Captain R. C.	96, Piccadilly, London, S. W. I.
3.3.1936	Griffiths, W. A.	Burmah-Shell Oil Company, Limited, Madras.
3.3.1936	Gue, Rai Sahib K. C.	District Engineer, Jalpaiguri, Bengal.
3.3.1935	Gue, T. C.	Chief Engineer, Rewa State.
26.6.1936	Guha, J. C.	Executive Engineer, Suburban Division, Calcutta.
24.9.1936	Gupta, Rai Bahadur J. N.	Executive Engineer, Golaghat Division, Jarhat (Assam).
5.4.1939	Gupta, Kanchanendu	District Engineer, Chaibasa, Singhbhum.
3.3.1936	Gupta, M. C.	Municipal Engineer, 38, Thornhill Road, Allahabad.
	Gupta, S. M.	Assistant Engineer, P. W. D., Pegu, Burma.
20.4.1939	Gupta, T. N.	C/o Mr. M. C. Gupta, M.I.E., Municipal Engineer, Allahabad (United Provinces).
12.6.1937	Guru, Ramamurty Pantulu	Public Works Supervisor, Vizagapatam Municipality, Vizagapatam.
20.9.1937	Guruswami, S.	Assistant Inspector of Local Works, Muzaffarpur.

Date of election.	Name.	Address.
23.5.1936	Haig, Lt. Col. W. de H., D.S.O.	Chief Engineer (retired), P. W. D., Buildings and Roads Branch, Lucknow.
3.3.1936	Hain, H. W. T.	Managing Director, Braithwaite & Co. (India) Limited, Hide Road, Kidderpore, Calcutta.
12.2.1937	Hainsworth, Major J. R.	Executive Engineer, Canals Division, Peshawar.
23.8.1937	Hall, Captain G. F., C.I.E., M.C.	Chief Engineer, P. W. D., Patna.
3.3.1936	Hardikar, J. C.	Executive Engineer, P. W. D., Warangal (N.S. Railway).
3.3.1936	Hardit Singh	Sub-Divisional Officer, P. W. D., Peshawar.
3.3.1936	Hari Chand, Rai Sahib	Concrete Association of India, 70, Queensway,, New Delhi.
24.6.1937	Harris, H. A	Executive Engineer, Provincial Division, Lahore.
4.12.1937	Harris, J.	District Board Engineer, Saharanpur.
3.3.1936	Harrison, C. P. M.	Chief Engineer, Department of Com- munications & Works, Calcutta.
4.3.1937	Hasany, M. U.	State Engineer, Tonk State, Tonk (Rajputana).
3.3.1936	Haval, Anant Balwant	Ilaka Panchayat Engineer, Shukhra- war Peth, Kolhapur.
8.12.1937	Hewitt, R. C. L.	Superintending Engineer, Orissa Circle, Cuttack.
9.1.1939	Hoey, G. Mc. C.	State Engineer, Jaipur State, (Rajputana).
1.6.1937	Hodgson, E. S.	Broadway Buildings, Westminster, London.
13.3.1936	Hoghshaw, F. H.	Superintending Engineer, P. W. D., Central Circle, Calcutta.
3.3.1936	Hughes, H.	Chief Engineer, Burma P. W. D., Rangoon.
3.3.1936	Ishtiaq Ali	Assistant Municipal Engineer, Delhi.

Date of election.	Name.	Address.
3.3.1936	Iyengar, N. Narasimha	Assistant Engineer, 1243, Weaver's line, Mysore
20.8.1936	Iyer, C. S. Venkatasubrahmanya	District Board Engineer, Kurnool.
9.12.1938	Iyer, E. V. S.	Assistant Engineer, P. W. D., P. O. Rayaguda, (N. S. Ry.)
11.10.1937	Iyer, M. K. Narasimha	Executive Engineer, Aryanapur, Shimoga District.
3.3.1936	Iyer, T. R. Ramaswamy	District Board Engineer, Tiruvanamalai, (Madras).
3.3.1936	Jagdish Prasad	Assistant to the Consulting Engineer to the Government of India (Roads), New Delhi.
16.11.1938	Jagmohan	Executive Engineer, 198, Tucker Road Agra.
3.3.1936	Jardine, A.	Director, Jessop & Company Limited, 93, Clive Street, Calcutta.
16.2.1938	Jay'swal, Rai Bahadur U. S.	District Engineer, Muzaffarpur.
3.3.1936	Jivrajani, M. R.	State Engineer, Porbander.
22.4.1937	Jivrajani, P. R.	Assistant Engineer, Khairpur Mirs', Sind.
22.4.1938	Joglekar, G. D.	Supervisor, District Local Board, Thana, (Bombay).
16.6.1938	Jones, F. T., C.I.E., M.V.O.	Chief Engineer, Central P. W. D., Simla/New Delhi.
12.1.1939	Jootla, B. S.	Sub-Divisional Officer, P. W. D., Sambalpur, (Orissa).
3.3.1936	Joshi, Rao Sahib N. S.	Assistant Engineer, 877, Sadashiv Peth, Poona.
3.2.1939	Joshi, Sitaram Balkrishna.	Engineer and Contractor, Examiner Press Building, Dalal Street, Fort, Bombay.
3.3.1936	Joti Prasad	District Engineer, Narsinghpur, (C. I.).
3.3.1936	Jussawala, J. R.	State Engineer, Cambay State.
3.3.1936	Kanhere, V. P.	State Engineer, Bhlor State.

Date of election.	Name.	Address.
1.10.39	Katarmal, C.L.	State Engineer, Orchha State, Tikamgarh, (C.I.).
3.3.1936	Katkoria, C. R.	State Engineer, Cutch State, Bhuj.
16.12.1937	Katrak, M. M.	153, Sappers Lines, Secunderabad.
3.3.1936	Keatinge, H. A.	Executive Engineer, Rajshahi, Bengal.
3.3.1936	Kelly, R. J.	Assistant Engineer Officer, Civil Aviation Office, New Delhi.
23.12.1937	Kerr, J. Oldfield	c/o The Burmah-Shell, P. O. Box 84, Karachi.
1.6.1936	Kerr, R. A.	c/o The Burmah Oil Company, Limited, Rangoon.
5.1.1939	Khan, Abdul Jabbar	Executive Engineer, Roads, P. W. D., Rampur State.
5.1.1938	Khan, Muhamed Abdul Khayyum	Divisional Engineer, Kareemnagar, H.E.H. the Nizam's Dominions.
15.6.1939	Khan, G. H.	Khan Manzil, Aerodrome Road, Srinagar (Kashmir).
16.1.1939	Khan, M. I.	Executive Engineer, Orissa P. W. D., Ganjam Division, Berhampore.
12.1.1938	Khan, N. M.	Divisional Engineer, Nirmal Division, Hyderabad (Deccan).
15.8.1939	Khan, M. A. Subhan	Assistant Engineer, P. W. D., Hydro-electric Survey Party, Drainage Secretariat, Hyderabad (Deccan).
3.3.1936	Khanna, I. N.	Asphalt Road Engineer, Standard Vacuum Oil Co. Engineer's House, Chhipiwara, Delhi.
3.3.1936	Khanna, Prem Nath	District Board Engineer, Muttra.
3.3.1936	Khatri, K. C.	Sub-Divisional Officer, P. W. D., Abbottabad
19.9.1936	Kidar Nath, Rai Sahib	Executive Engineer, P. W. D., Buildings and Roads Branch, Jullundur Cantonment.
20.11.1936	Kikkeri, S. A.	Shalimar Tar Products (1935) Limited, 2/29, Mount Road, Madras.
17.6.1938	Kirk, E. S.	C/o Braithwaite Burn & Jessop Construction Company, Calcutta.

Date of election.	Name.	Address.
3.3.1936	Korni, Dr. M. A.	Chief Engineer, Reinforced Concrete Department, Bird & Co. Limited, P. O. Box No. 264, Calcutta.
1.12.1936	Kunte, Vaman J.	State Engineer, Jamkhandi.
13.1.1937	Kurian, J.	Engineer to the Corporation of Madras, Rippos Buildings, Park Town, Madras.
13.3.1937	Kutty-Krishnan, O. C.	Roads Engineer, The Standard Vacuum Oil Co., Thamichetty Street, Madras.
3.3.1936	Kynnersley, T. R. S.	The Associated Cement Companies Limited, Forbes Buildings, Home Street, Bombay.
1.10.1938	Lakshman Swarup	Assistant Engineer, P. W. D., Moradabad.
26.5.1937	Lakshminarasimhaiya, N.	Executive Engineer, Bangalore.
3.3.1936	Lal, Brij Mohan	Executive Engineer, 52, Jail Road, Lahore.
3.3.1936	Lang-Anderson, Major W. G.	Superintending Engineer, P. W. D., Bannu.
9.1.1937	Lawson, A. Burns	The Hindustan Construction Company Limited, Ballard Estate, Bombay.
29.8.1936	Lawley, W.	Executive Engineer, P.W. D., Bannu.
3.3.1936	Lekh Raj	Civil Engineer, Kapurthala State.
25.3.1937	Lloyd, M. E.	Asphalt Engineer, Standard Vacuum Oil Co., 6, Church Lane, Calcutta.
6.1.1938	Lokendra Bahadur	Executive Engineer, P. W. D., Raichur.
3.3.1936	Mackenzie, R. H. T.	Chief Engineer, Bikaner State, Bikaner.
3.3.1936	Madhav, S. K.	Assistant Engineer, Indore City Municipality, Indore.
13.6.1936	Mahabir Prasad	Superintending Engineer, P. W. D., Agra.

Date of election.	Name.	Address.
11.1.1939	Mahapatra, M.	Supervisor, P. W. D., Sunki, P. O. Pottangi, District Koraput.
6.1.1939	Malhotra, Ajit Chand	Chief Engineer and Secretary, P. W. D., Patiala.
3.3.1936	Malhotra, B. R.	Executive Engineer, P. W. D., Dera Ismail Khan.
3.3.1936	Malik, Sardar Bahadur T. S., C. I. E.	Superintending Engineer, Central P. W. D., New Delhi.
3.3.1936	Manohar Nath	100, Babar Road, New Delhi.
3.3.1936	Mathew, P. G.	District Board Engineer, South Arcot, Cuddalore N. T.
8.4.1939	Mathur, Kishore Lal	Assistant Executive Engineer, P. W. D., Jodhpur, (Rajputana).
18.3.1936	McIntosh, R.	Executive Engineer's Bungalow, Waltair, Vizagapatam District.
3.3.1936	McKelvie, G. M.	Superintending Engineer, Aviation Circle, New Delhi.
1.5.1936	Meares, C. D. N.	C/o Standard Vacuum Oil Co., 6, Church Lane, Calcutta.
30.3.1938	Mehra, S. R.	Officer on Special Duty, Communications Board, P. W. D., Secretariat, Lahore.
3.12.1938	Mehta, Framroz D.	Chartered Engineer, 63, Ferguson Road, Bombay 13.
3.3.1936	Mehta, Jagmohandas T.	Town Roads Supervisor, Vadva, (Bhavnagar State).
3.3.1936	Mehta, Iqbal Narain	Municipal Engineer, Multan.
22.9.1937	Mehta, N. N.	Central P. W. D., Beawar, (B. B. and C. I. Railway).
24.1.1939	Menon, V. K. Aravindaksha	Chief Engineer, Cochin Government, Trichur.
24.2.1937	Meswani, V. M.	Indian Hume Pipe Company, Construction House, Ballard Estate, Bombay.
11.1.1939	Mirza, M. A.	Assistant Engineer, P. W. D., B. & R Branch, Cawnpore.

Date of election.	Name.	Address.
3.3.1936	Mitchell, K. G., C. I. E.	Consulting Engineer, to the Government of India (Roads), Simla/New Delhi.
3.2.1939	Mitra, Tinkara	Executive Engineer, Darjeeling Division, Darjeeling.
3.3.1935	Modak, N. V.	City Engineer, Bombay Municipality, Hornby Road, Fort, Bombay.
1.1.1937	Modi, A. K.	The Navsari Electric Supply Company Limited, Navsari.
6.1.1938	Mohammad Ibrahim	Executive Engineer, P. W. D., Asifabad, Hyderabad (Deccan).
28.3.1939	Mohomed Usman	Assistant Engineer, P. W. D., Lingsugur, (Raichur Dist.).
3.3.1936	Mookerjee, B. N.	C o Martin and Company, 12, Mission Row, Calcutta.
2.12.1937	Mookerjee, R. N.	8, 3, Loudon Street, Calcutta.
30.9.1936	Morgan, I.	103, Clive Street, Calcutta.
3.6.1935	Morris, A. E. C.	Branch Manager, McKenzies Limited, Esplanade, Madras.
3.3.1936	Mudaliar, T. Lokanatha	District Board Engineer, Coimbatore.
29.1.1937	Mufti, M. I. D.	A. C. R. E. Works, P and A. District, Fort William, Calcutta.
3.3.1936	Mukerjee, Rai Bahadur A. C.	Executive Engineer, Provincial Division, Lucknow.
21.2.1938	Mukerji, U. N.	Executive Engineer, 29, Parashor Road, P. O. Kalighat, Calcutta.
7.1.1937	Mukherji, P. K.	District Board Engineer, Masulipatam, (Kistna District).
4.5.1936	Murari Lal	Assistant Engineer, 'B' Provincial Sub-Division, Lahore.
9.6.1936	Murrell, W. L.	Superintending Engineer, North Bihar Circle, Muzaffarpur.
21.1.1939	Murti, N. V. S.	Executive Engineer, Dharwar.
3.3.1936	Nadirshah, E. A.	Improvement Trust Building, Napier Road, Fort, Bombay.
5.11.1936	Naidu, R. B. Gobindaswami	Assistant Engineer, Cuddapah, (Madras).

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17.1.1938	Nambiar, K. K.	District Board Engineer, South Kanara, Mangalore.
3.3.1936	Nanda, B. D.	Divisional Engineer, Banihal Road Division, Udhampur.
9.1.1939	Nanda, K. L.	Divisional Engineer, Kashmir Division, Srinagar.
16.6.1939	Nangea, Gaupat Rai	Sub-Divisional Officer, Dhok Pathan Proon Sub-Division, P. W. D., (B. & R.), c o Postmaster, Pindigheb, District Attock.
9.6.1936	Naqvi, M. H.	Executive Engineer, P. W. D., Nizamabad, Hyderabad (Deccan).
3.3.1936	Narasimham, J. S.	3393, Kingsway, Secunderabad.
19.1.1938	Narayanamurty, B.	L. F. Assistant Engineer, Gudivada, Kistna District.
23.11.1936	Narayanaswami, S.	District Board Engineer, North Ramnad, Tirupathur.
3.3.1936	Nat, Gopal Singh	Civil Engineer, Canal Rest House, Jodhpur, P. O. Sarai Sidhu., District Multan.
7.8.1936	Nath, Raj Mohan	Assistant Engineer, P.W.D., Nowgong, (Assam).
10.7.1936	Nayar, D. P.	Executive Engineer, Provincial Division, Simla.
30.9.1936	Nayar, P. T. Narayana	Special District Board Engineer, Calicut, Malabar.
9.11.1937	Naziruddin, K.	Superintending Engineer, Orissa Circle, Cuttack.
3.3.1936	Newton, B. St. J.	Officiating Superintending Engineer, Raipur, (Central Provinces).
19.3.1936	Nicolson, J. F. H.	Chief Public Works Officer, Federated Shan States, Taunggyi, Burma.
5.8.1939	Nicolaides, E. P.	Chief Designer, Messrs. J. C. Gammon Limited, Hamilton House, Bombay.
3.3.1936	Nilsson, D.	Chief Engineer and Director, J. C. Gammon, Limited, Hamilton House, Graham Road, Ballard Estate, Bombay.

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3.3.1936	Northey, Lt. Col. H. S.	Superintending Engineer, P. W. D., P. O. Modigere, Kadur District.
19.3.1936	Nougerede, C. E. de la	Assistant Garrison Engineer, Shillong.
3.3.1936	Oram, A.	Chief Engineer and Secretary to the Government of N. W. F. P., P. W. D., Peshawar.
13.1.1937	Pancholi, D. B.	State Engineer, Dhrangadhra State, Dhrangadhra.
18.5.1939	Pancholy, H. M.	Kundan Lal Buildings, Dharam Peth, Nagpur (C. P.).
3.3.1936	Panje, Shanker Rao	District Board Engineer, Anantapur.
14.3.1936	Parikh, H. B.	Special Road Engineer in Sind, (on leave), P. W.D., Karachi.
10.1.1938	Parmara, S.	A. P. Sen Road, Lucknow.
23.11.1936	Patel, B. D.	Special Road Engineer, Sind, P.W.D., Karachi.
3.3.1936	Patel, M. R.	Executive Engineer, Navsari (Baroda State).
3.3.1936	Pearce, E. O.	Departmental Manager, Engineering Department, Bird and Co., Chartered Bank Buildings, Calcutta.
10.7.1936	Pennell, K. E. L.	Chief Engineer and Secretary to the Government of Assam, P. W. D., Shillong.
20.1.1937	Pillai, N. P. Sundaram	District Board Engineer, Negapatam.
28.3.1937	Plumley, D. J.	State Engineer, Bastar State, Jagdalpur.
16.5.1939	Prasad, A. P.	Sub-Divisional Officer, P. W. D., P. O. Hazaribagh, (Bihar).
3.1.1939	Puranik, R. G.	Assistant Engineer, Jamkhandi State.
25.3.1939	Puri, Dr. A. N.	Physical Chemist, Punjab Irrigation Research Institute, Lahore.
23.1.1939	Puri, B. S.	Superintending Engineer, Central Aviation Division, Council House Street, Calcutta.

Date of Election.	Name.	Address.
3.3.1936	Raghava Acharya V. S. Srinivasa	District Board Engineer, Trichinopoly.
3.3.1936	Raghavachary, K. S.	Assistant to the Special Engineer, Road Development, Madras.
24.11.1936	Rajam, M. K.	Executive Engineer, Buildings Division, Bangalore.
23.7.1936	Raju, P. Venkataramana	Executive Engineer, P. W. D., Trichinopoly.
3.3.1936	Ramamurti, K. S.	District Board Engineer, Vizagapatam
10.2.1937	Ramanujacharya, S.	Assistant Engineer, Public Works Department, Anantapur (Madras Presidency).
19.7.1937	Ramannjam, M.	Executive Engineer, Kadur Division, Chikmagalur, Mysore.
3.3.1937	Ramaswamy, H.	District Board Engineer, Bijapur, Bombay Presidency.
4.1.1937	Ranade, D. H.	C o Messrs. Ranade Brothers, Engineers and Contractors, 653, Budhwar Peth, Poona 2.
3.3.1936	Rangaswami, K.	State Engineer, Pudukkottai State, Pudukkottai.
3.3.1936	Rangaswami, V. N.	Road Engineer, Burmah-Shell Co. Madras.
3 3.1936	Rangaswami, V. S.	Assistant Engineer, District Board, West Tanjore.
9.7.1936	Rangaswamy, Rao Sahib M. A.	District Engineer, Dharbhanga.
3.3.1936	Rao, A. Lakshminarayana	District Board Engineer (on leave) Prakasam Road, Tyagarajnagar, (Madras).
4 2.1939	Rao, B. Krishna	Executive Engineer, Well Sinking Department, Sholapur, District Gulbarga.
3.5.1938	Rao, C. Hanmanth	Divisional Engineer, Parbhani.
3.3.1936	Rao, G. Sheshagiri	Executive Engineer, Krishnaraj Sagar, Mysore State.

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30.8.1937	Rao, H. R. Sayoji	Assistant Engineer, District Board, Kistna, Masulipatam.
5.9.1936	Rao, K. Subba	Municipal Engineer, Guntur.
3.3.1936	Rao, N. Subha	Superintending Engineer, Mysore Circle, Mysore.
20.6.1938	Rao, Sridhar	District Board Assistant Engineer, Gobichattipalayam, Coimbatore District.
19.12.1938	Rao, V. Venkatappa	District Board Engineer, Ganjam, Chatrapur (Orissa).
3.3.1936	Ratnagar, R. D.	Executive Engineer, P.W.D., Jubbulpore.
21.10.1936	Rau, D. Madhava	L. F. Assistant Engineer, Angola District Board, Bapatla, Guntur District.
3.3.1936	Ray, G. P.	District Engineer, Puri.
30.7.1936	Rege, D. Y.	C o Standard Vacuum Oil Company, Neville House, Ballard Estate, Bombay.
3.3.1936	Rege, S. B.	Excutive Engineer, Ratnagiri Division, Ratnagiri.
3.3.1936	Roberts, S. A.	Partner, Bird & Co., Chartered Bank Buildings, Calcutta.
10.7.1936	Romesh Chandra	Executive Engineer, Tezpur, (Assam).
3.3.1936	Rowlands, W. H.	Technical Assistant, Burmah-Shell Oil Company, Limited, New Delhi.
6.1.1938	Roy, C. B.	Executive Engineer, Chindwara.
20.1.1939	Roy, J. C.	State Engineer, P.W.D., Cooch-Behar.
3.3.1936	Sadarangani, V. H.	Professor of Civil Engineering, College of Engineering, Madras, Saidapet.
15.6.1939	Saha, S. I.	C/o B. Raghunath Sahai, Pleader, M. P. Bagh, Arrah (Bihar).
3.3.1936	Sahgal, Rai Sahib Sant Ram	State Engineer, Mewar State, Udaipur.
3.3.1936	Sahrey, J. C.	Assistant Engineer, P.W.D., Gorakhpur, (United Provinces).

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3.3.1936	Saksena, C. P.	Assistant Engineer, P. W. D., Rewa State, Sidhi', (B. N. Ry.).
3.3.1936	Sanjana, N. P.	Engineering Assistant, Chief Engineer's Office, Bombay Port Trust, Ballard Estate, Fort, Bombay.
5.1.1937	Sankaram, G. B.	I. F. Assistant Engineer, Gudivada, Kistna District (Madras Presidency).
30.9.1936	Sarabhoja, N.	Superintending Engineer, Irrigation Circle, (K. R. S. Works), Bangalore.
22.2.1937	Sarkar, R. K.	Municipal Engineer, (Retired) Lucknow.
10.11.1936	Satyanarayana, B.	District Board Engineer, Rajahmundry, East Godavary.
3.3.1936	Scaldwell, R. W.	Superintending Engineer, Mysore Circle, Bangalore.
18.3.1936	Scott, G. E.	Superintending Engineer, Prom Court, Rangoon.
13.1.1939	Sekharan, T.	District Engineer, District Board, Madura.
16.1.1939	Sen, A. K.	Road Engineer, Tripura State, P. O. Agartala.
15.11.1938	Sen Gupta, L. C.	District Engineer, Rangpur.
23.1.1939	Senapaty, G. N.	Sub-Divisional Officer, P. W. D., Kendupatna Sub-Division, P. O. Kendupatna, District Cuttack.
3.3.1936	Shah, V. J.	Engineer to Khan Bahadur M. A. K., Mackawee, O. B. E., Government Contractor, Maidan Road, Camp Aden, Arabia.
29.9.1936	Shahani, C. M.	C/o Braithwaite Burn and Jessop Construction Co., Mercantile Building, Lall Bazar, Calcutta.
3.3.1936	Shannon, Ian. A. T.	Burma-Shell Co., Hongkong House, P.O. Box 360, Calcutta.
3.3.1936	Shareef, Safdar Ali	Estate Engineer, Nawab Salar Jung Bahadur, Dewan Dewdi, Hyderabad State.

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3.3.1936	Sharma, Hari Shankar	District Board Engineer, Meerut.
4.8.1936	Sharma S. S.	District Engineer, Almora.
3.3.1936	Shenoy, B. Narasimha	District Board Engineer, Calicut, Malabar District.
1.10.1939	Shete, Diwan Bahadur V. G.	322/2, Sadashiva Peth, Poona.
13.3.1936	Shivdasani, K. J.	Chief Officer and Engineer, District Local Board, Larkana, (Sind).
5.12.1938	Sinha, A. K.	District Engineer, District Board, Cuttack.
1.7.1939	Sinha, B.	Assistant Engineer, P. W. D., Purulia, (Bihar).
27.11.1936	Sinha, H. P.	Executive Engineer, Central P. W. D., New Delhi.
22.3.1937	Sirajuddin, P.	District Board Engineer, Cuddapah, (Madras).
3.2.1939	Siri Ram	Chartered Engineer, 10, The Mall, Lahore.
3.3.1936	Smith, Lt. Col. H.C., O.B.E.	General Secretary, Indian Roads and Transport Development Association, 41, Nicol Road, Ballard Estate, Bombay.
25.7.1938	Sohan Lal	Assistant Engineer, P. W. D., Balasore, (B. N. Ry.).
3.3.1936	Sondhi, R. L.	Executive Engineer, Ambala.
3.3.1936	Sopwith, Colonel G. E.	C o Messrs. Turner Morrison and Co. Limited, 6, Lyons Range, Calcutta.
3.3.1936	Sowani, D. G.	Civil and Hydrauladi, Tardeo Rama Nivas, Chilkhalwadi Tardio Road Bombay No. 7.
3.3.1936	Sri Narain, Rai Bahadur	Executive Engineer, Lucknow.
3.3.1936	Srinivasachari, M. A.	Retired Superintending Engineer, 80, Budh Temple Road, Basavangudi, Bangalore City.
3.3.1936	Srinivasamurti, K. V.	Assistant Engineer, No. 1 Sub-Division, P. W. D., Mysore.

Date of election.	Name.	Address.
8.11.1937	Srinivasan, K.	L. F. Special Assistant Engineer, Narasapatam.
3.3.1936	Srivastava, Madho Prasad	District Board Engineer, Lucknow.
10.12.1937	Stanier, T. W.	C o Aveling-Barford, Limited, Grantham, England.
3.1.1939	Stein, J. A.	Special Officer, Road Fund Works, Bengal, Calcutta.
3 3.1936	Stevens, Lt-Col. A. E.	Commanding Royal Engineer, Meerut District Headquarters, Dehra Dun.
4.5.1936	Stuart Captain James	Executive Engineer, P.W.D., Bannu.
5.2.1937	Stuart-Lewis, Allan	C/o Concrete Association of India, 12, Mission Row, Calcutta.
3.3.1936	Stubbs, S. G., O. B. E.	Clifdon, P. O. Raison, Kulu, District Kangra.
3.3.1936	Subrahmanyam, Ramachandra	Executive Engineer, Madura Municipality, Madura.
3.3.1936	Sujan, S. B.	District Engineer, Concrete Association of India, Queens Road, Karachi.
9.3.1937	Sukhatankar, V. M.	District Engineer, District Local Board, Belgaum.
13.5.1936	Sundaresan, T. V.	Chartered Civil Engineer, New Colony, Nagpur.
3.3.1936	Sunder Lal, Rai Bahadur	Superintending Engineer, P. W. D., Nagpur.
3.3.1936	Surati, H. M.	Assistant Engineer, Vallabhdas Estate, Public Garden Road, Hyderabad (Deccan).
23.1.1939	Tandy-Green, C. W.	Chief Engineer, Bengal Communications and Works Department, Calcutta.
14.3.1936	Todd, J. M.	Executive Engineer, P. W. D., Secretariat (B. & R.), Prome Court, Burma.
3.3.1936	Tonks, H. J.	Executive Engineer, Rangoon Corporation, Rangoon.
23.3.1936	Trevor-Jones, R., M. C.	Superintending Engineer, Third Circle, Lahore.

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24.6.1936	Tripathi, S. N.	Assistant Engineer, P. W. D. Khamgaon, (Berar).
18.5.1937	Trollip, A. S.	General Manager, The Bombay Electric Supply and Tramway Co Limited, Electric House, Fort, Bombay.
3.3.1936	Turab, Mohamad Abu	Superintending Engineer, P. W. D., Medak, Nizam's Dominions.
3.3.1936	Turnbull, W. J.	C/o Shalimar Tar Products (1935) Limited, P. O. Box No. 194, Bombay.
3.3.1936	Tweed, Rathlin J. C.	Works Manager, Braithwaite & Co. (India) Limited, Calcutta.
3.1.1939	Tyabji, S. B.	Chief Engineer, P. W. D., Jammu.
3.3.1936	Vagh, Balwant Vitthal	Road Engineer, Burmah-Shell Oil Distributing Company of India Limited, Bombay.
1.12.1937	Vaishnav, S. G.	Personal Assistant to the Chief Engineer, Baroda.
30.9.1936	Vakil, Rai Sahib N. H.	District Engineer, P. O. Motihari, Champaran.
3.3.1936	Varma, Rai Bahadur A. P.	Chief Engineer, Bikaner State, Sri Ganganagar.
3.3.1936	Varma, R. I.	Executive Engineer, P. W. D., K. and J. Hills Division (Assam), Shillong.
3.3.1936	Vaswani, G. B.	Assistant Engineer, Roads, Karachi Municipality, Karachi.
3.3.1936	Venkatakrishnan, Rai Bahadur Lakshminarayana Aiyar	Superintending Engineer, Bellary Circle, Bellary.
13.3.1936	Vesugar, J.	Under Secretary to the Government of Punjab, P. W. D., Building and Roads Branch, Lahore.
3.3.1936	Vipan, A., C.I.E.	Chief Engineer and Secretary to the Government of Orissa, P. W. D., Cuttack.
18.7.1938	Viraraghavan, E.	Divisional Engineer, H.F.H. Nizam's P. W. D., Nanded.

Date of election.	Name.	Address.
3.3.1936	Wadley, K. L. H.	Executive Engineer, Viceroyal Estates, New Delhi.
13.9.1937	Wale, N. D.	Engineer, Municipal Borough, Hubli, District Dharwar.
18.6.1936	Walker, Brigadier E. C.	Chief Engineer, Southern Command, Poona.
3.3.1936	Walker, W. F., M.C.	Superintending Engineer, P. W. D. Lucknow.
3.3.1936	Warren, P. F. S.	Director, Jessop & Co. Limited, 93, Clive Street, Calcutta.
29.5.1936	Wellwood, F. D.	Chief Engineer, Mayurbhanj State Baripade (Eastern States Agency).
1.5.1936	Whishaw, Lt. Col. W.B., O.B.E., M.C.,	Commanding Royal Engineer, Independent, Brigade Area, Karachi.
3.3.1936	Whitby, A. B.	Executive Engineer, P.W.D., Hoilem, Burma.
17.5.1937	Willcocks, H.	Superintending Engineer, Central P. W. D., New Delhi.
3.3.1936	Winkler, L. A. H.	Superintending Engineer, Mysore P. W. D., Cunningham Crescent, Bangalore.
10.7.1936	Wooltorton, F. L. D.	Executive Engineer, Shwebo Division, Shwebo, Burma.
11.9.1939	Zaman, Chowdhury Imamuz	Sub-Divisional Officer, P. W. D., Jorhat.
13.9.1937	Zutshi, M. N.	Engineer, District Board, Gorakhpur.

ASSOCIATE MEMBERS.

20.12.1937	Armitage, Edgar	C/o Messrs. Grindlay & Company, Bombay.
29.2.1936	Chinoy, Nurmohamed M.	C/o The Bombay Garage, Chowpatty, Bombay.
27.10.1937	Davidson, J. C. F.	C/o Messrs. Bird & Co. Oriental Buildings, Lahore.
21.2.1938	Ford, T. S.	C/o The General Motors (India) Limited, Bombay.
25.11.1938	Hayward, E.	C/o D. Wallie and Co. Konnagar, District Hoogly.

Date of election.	Name.	Address.
18.3.1936	James, Hugh	Burmah-Shell House, Ballard Estat Bombay.
29.2.1936	Kerr, W. H.	District Sales Manager for Northern India of Bitumen Emulsions (India), Limited, C/o The Rawalpindi Club, Rawalpindi.
1.6.1939	Khan, Nasrat Mohammed	Secretary, Law and Justice, Jaora Durbar, Jaora. (Central India).
10.1.1939	Malani, C. T. S.	C/o Messrs. Standard Vacuum Oil Co., Finlay House, Karachi.
29.2.1936	Marschalko, Th. C.	C/o Caltax Company (India) Limited Bombay.
29.2.1936	Moss, G. L. W.	Technical Service Manager, Dunlop (India) Limited, 39, Free School Street, Calcutta.
25.2.1939	Munday, P.	C/o Burmah Shell Oil Storage and Distributing Co. of India Limited, Calcutta.
29.2.1936	Ormerod, H. E.	Forbes Buildings, Home Street, Bombay.
30.9.1936	Pennyquick, J. R.	C/o Messrs. Birch Marve and Co. Limited, Bagdad (Persia).
20.9.1936	Smith, J. W.	C/o Standard Vacuum Oil Company, Calcutta.

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Name of the Advertiser	Products, etc.	Pages.
Associated Cement Companies, Ltd. ..	Cement	(i), (ii) & (ix)
Braithwaite, Burn and Jessop Construction Company, Ltd.	Licensees for Franki Piles and General Engineering Constructions	(iii) & (iv)
Burmah Shell Oil Storage and Distributing Company of India, Ltd.	Road Surfacing Materials ..	(xviii)
Ford Motor Co. of India, Ltd.	Motor Trucks	(xii)
General Motors India, Ltd.	Motor Trucks	(xiii)
Hindusthan Engineering & Construction Company	Engineers, Builders and Contractors	(vii)
Indian Roads Congress	Publications for Sale	(viii) & (xvii)
Imperial Chemical Industries (India), Limited	Dunlop equipment for Vehicles	(v)
John Fowler & Co. (India), Ltd. ..	Steam and Diesel Road Rollers	(vi)
Krupp Indian Trading Co., Ltd. ..	Kemna Die 1 Rollers. ..	(xiv)
Lawrence & Mayo Ltd.	Surveying Instruments ..	(xvii)
Marshall Sons & Co. (India), Ltd. ..	Marshall Road Rollers ..	(i)
Millars' Timber & Trading Co., Ltd. ..	Road Plant	(xvi)
Shalimar Tar Products (1935), Ltd. ..	Road Tar	(v)
Standard-Vacuum Oil Co.	Road Surfacing Materials ..	(xi)

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The Secretary,
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